The chemical and physical characterization of soils with andic properties in the atlantic zone of Costa Rica.

Jetse Stoorvogel

1989

Agricultural University
Wageningen.

Preface

As a part of my study in tropical soil science at the Agricultural University in Wageningen, I stayed 11 months in the Atlantic zone of Costa Rica. Purpose of my stay in Costa Rica was to visit the project of the Agricultural University in co-operation with the ministry of agriculture and fishery (MAG) and the "Centro Agronomico Tropical de Investigacion y Ensenanza" (CATIE). The first six months were used for a practical training period resulting in a soil map at a scale of 1:50.000. During this period the soils with andic properties drew my interest mainly due to problems, we had, with the classification of these soils and due to the typical characteristics of these soils. This interest resulted in this study.

During this study I received a lot of help and advise from various persons and institutes. To each of them I offer grateful thanks. The following persons and institutes I would like to thank in particular: Willem Wielemaker, the project of the Agricultural University in co-operation with CATIE and MAG, ASBANA, prof. N. van Breemen, L. Th. Begheijn, W.J. Ackerman and ISRIC.

Jetse Stoorvogel
february 1989

TABLE OF CONTENTS

APPENDICES

1. Introduction

1.1 The area of investigation.

The area of investigation is situated in the western part of the Limon province of Costa Rica (Appendix 1). The area is almost homogeneous in terms of climate with a total annual rainfall around the 4500 mm and a mean annual temperature of about 24 C. The area is situated at the foot of the Cordillera Central. This chain of mountains is dominated by a large number of volcanoes. The parent material of the area originates from these volcanoes (Irazu and Turrialba) and is transported by large braided rivers and by mud-flows. In many cases it is very hard to determine the type of sediment, although volcanic ashes do occur in almost all kinds of sediments in this area.

1.2 Objectives

In 1988 ICOMAND (1988) proposed a new classification for the volcanic ash soils. Main objective of this study is to describe the effect of the new classification on the soils of the area of investigation. This requires the execution of some specific chemical, physical and mineralogical analyses. It has not been possible to perform mineralogical analyses for this study.

Besides the classification of the soils, a good chemical and physical characterization of the soils should be carried out. This requires a wide spectrum of all kinds of physical and chemical analysis.

The classification of soils is a very important element of soil science. In the case of the volcanic ash soils (Andisols) some complex and expensive analysis are required for detailed characterization. To minimize the analyses, a field criterion

highly correlated with the required analysis should be found. If a field criterion for the Andisols can be found this could replace the analysis as proposed by ICOMAND (1988) for the classification of Andisols.

Compaction of the topsoil is a common phenomenon in this area. Describing the general characteristics of the Andisols, a question to be asked is if the andic properties of the soil material change during compaction. If the andic properties would disappear due to compaction this would have consequences for the classification.

1.3 Backgrounds

At this moment Soil Taxonomy of the soil survey staff (1975) is a widely accepted system of soil classification. In Soil Taxonomy the volcanic ash soils with andic properties fall in the order of the Inceptisols and in the suborder of the Andepts or in the Aquepts. The Aquepts are keyed out before the Andepts and therefore are Andisols with an aquic moisture regime classified as Aquepts. At the level of great group these soils fall in the Andaquepts. To fall in the suborder of the Andepts or in the great group of the Andaquepts the following requirements must be met to a depth of 35 cm or more or to a lithic or paralithic contact if this is shallower than 35 cm:

1. a: The exchange complex of the clay at pH 8.2 is >150 meq per 100 g measured clay, and commonly >500 meq per 100 g.
   b: If the moisture content at pF 4.2 is more than 20 % the pH NaF after 2 minutes is >9.4.
   c: The ratio of 15-bar water content to measured clay is more than 1.0.
   d: The amount of organic carbon is >0.6%.

e: The bulk density is <0.85 g per cubic centimeter at 1/3 bar-tension.

or 2: 60% or more of the soil is pyroclastic material.

It is recognized that the classification of the soils of the tropics has lagged behind for lag of data. This was one of the reasons for the creation of international committees to improve the classification of tropical soils (Eswaran, 1981). ICOMAND is the international committee on the classification of Andisols which reconsiders within the framework of Soil Taxonomy the classification of the volcanic ash soils. In 1988 the final ICOMAND circular (ICOMAND, 1988) was published. The proposal of ICOMAND out of the addition of a new order and two new subgroups. This new order of the Andisols keys out all the mineral soils which have andic properties, as defined in appendix 2, throughout all subhorizons, whether buried or not, which make up a thickness of 35 cm or more within 60 cm of the mineral soil surface if no lithic or paralithic contact occurs within 60 cm of the mineral soil surface. The andic subgroup is defined as soils which have throughout a minimum cumulative thickness of more than 18 cm in the upper 75 cm, a bulk density of the <2 mm fraction, measured at 33 KPa water, of 1.0 g per cubic centimeter or less and acid-oxalate-extractable aluminum plus 1/2 acid-oxalate-extractable iron of more than 1.0%. The vitrandic subgroup is defined as soils which have, throughout a minimum cumulative thickness of 18 cm in the upper 75 cm:

a. Volcaniclastic material coarser than 2 mm constituting more than 60% by volume of the whole soil, or

b. A 0.02 - 2.0 mm fraction, as determined on undried samples, which constitutes at least 30% of the <2 mm fraction and which contains more than 30% volcanic glass.

The primary diagnostic horizon of certain Andisols is the melanic epipedon. This is a thick black horizon (or horizons), occurring at or near the surface, containing high concentrations of organic carbon, usually associated with short-range-order minerals or aluminum-humus complexes. The melanic epipedon is defined as:

1. colors, organic carbon content and structure of a mollic or umbric epipedon, and an upper boundary at, or within 30 cm of the surface.
2. In a cumulative thickness of 30 cm or more within a total thickness of 40 cm -
   a. Moist Munsell value and chroma of 2.0 or less throughout and
   b. 8 percent or more organic carbon as a weighted average and no less than 4 percent organic carbon in any subhorizon.

In the classification system used for the legend of the soil map of the world (FAO-UNESCO, 1974) the volcanic ash soils are keyed out at the highest level as andosols. This classification system will not be used in this study.

Although volcanic ash soils are different all over the world there are some general characteristics. Some general characteristics of the volcanic ash soils that almost all authors in the literature agree on are:

- deep, mostly stratified profiles,
- dark colors and a high organic matter content in the topsoil,
- yellowish brown subsoil,
- a low bulk-density and a high water retaining capacity,
- weak structures,
- slightly sticky, slightly plastic and thixotropic,
- high variable charge.

(Wright, 1964; Swindale, 1969; Scheffer and Schachtschabel, 1984; etc.)

These characteristics are mostly describing a well developed Andisol. A young Andisol has coarse textures with a high content of volcanic glass. During the weathering of the volcanic glass the typical characteristics of the Andisols develop.

2. Methods

2.1. Selection of the pits.

The project UAW-CATIE-MAG has three pilot areas (Neguev, Río Jiménez and Cocori). At the start of this investigation, soil maps of these areas and one of the area north from Guapiles were available. The soils used in this study are selected from these four areas. The main soil types with andic properties were selected. For determining the effect of compaction on andic properties, one very compacted profile in Cocori (COC 25) and one in the Neguev (Eg 4) were added to the list. The soils in the Neguev area (Eg 3 and Eg 4) were not really Andisol-like except for the thixotropy, for a better study a similar profile was added but without thixotropy (Eg 2).

2.2 Field methodology.

In the first place a representative profile of the selected soil type should be found. This selection was already made during the soil survey. After retrieving this site and if necessary reopening the pit, the profile description was checked. The descriptions were all standardized by checking and interpretation differences by various authors were eliminated. In some cases it was impossible to check the deepest horizons, due to the high groundwater table.

Of every horizon three 100 cc rings with undisturbed samples and about 4 kg disturbed sample were taken. The 4 kg disturbed sample was after mixing split up into various samples, part of which were airdry and part of which were kept field moist:

1. airdry sample (1 kg) for analysis in the laboratory of the MAG.

2. airdry sample (0.5 kg) for chemical analysis.
3. airdry sample (0.25 kg) for physical analysis.
4. moist sample (0.75 kg) for chemical analysis.
5. moist sample (0.5 kg) for physical analysis.
6. rest sample (airdry) of approximately 1 kg for further investigations.

2.3. Laboratory methods.

Except for the bulk density and the analysis carried out by the MAG and the CATIE all analysis were performed on air-dried samples (which are re-wetted if the analysis requires a moist sample) and on moist samples, which were not dried for any analysis.

2.3.1. Physical analysis.

As physical analyses the following characteristics are determined:

- Liquid limit, plastic limit and plasticity index according to ASTM standards (ASTM, 1981).
- Bulk density, with the aid of three 100 cc rings, which were pushed in the undisturbed profile. All profiles were more or less at field capacity during sampling. The samples are weighed, dried during 24 hours at 105 C and weighed again.
- moisture content at pF 4.2. using a pressure membrane apparatus.
- texture, carried out in the laboratory of the MAG. The samples were treated with hydrogen peroxide for destroying the organic matter and with sodium hexametaphosphate and sodium hydroxide for dispersing. After this treatment the texture

is determined with the hydrometer method with 2 readings after 2 minutes for the sand fraction and after 60 minutes for the clay fraction. Kubota (cited by Warkentin and Maeda, 1980) already indicates the danger of texture analyses on volcanic ash soils. All the samples for texture analyses were air-dry before the analysis. Drying the samples can mean a large change of texture.

2.3.2. Chemical analysis.

Before starting the analyses the water content (@ in g/g dry soil) of all the moist samples is determined.

-pH-H2O dry: 10 g air-dry soil is shaken for 3 hours with 25 ml of water, whereafter the pH is measured with a combination electrode.

wet: An equivalent of (10 + @*10)g moist soil is shaken for 3 hours with (25 - @*10) ml water, whereafter the pH is measured.

-pH-KCl dry: 10 g air-dry soil is shaken for 3 hours with 25 ml of 1 n KCl solution, whereafter the pH is measured.

- wet: (10 + @*10)g moist soil is shaken for 3 hours with 12.5 ml of 0.2 n KCl solution and (12.5 - @*10) ml water, whereafter the pH is measured.

-pH-NaF - dry: described by Reeuwijk (1986) with measurements after 2 and 60 min.

- wet: The same procedure but with (1 + @) g moist soil instead of 1 g air-dry soil.

-phosphate retention: method of retention described by Reeuwijk (1986). To determine the phosphate content the following solution is used:

5 ml of: 0.50 (g) methol,
2.50 (g) Na2SO3,
68,50 (g) Na2S2O5 in 500 ml water.

5 ml of: 25 (g) (NH4)6Mo7O24.4H2O,
70 (ml) concentrated H2SO4 in 500 ml water.

10 ml of: 320 (g) CH3COONa.3H2O in 1 (l) water.

The absorption is measured at a wavelength of 685 nm.

- Acid oxalate extractable Al, Fe and Si as described by Reeuwijk (1986).
- KOH extractable Al as described by Holmgren and Kimble (1984).
- Organic matter according to Walkley and Black carried out in the laboratory of the MAG.
- CEC, determined in the laboratory of the MAG with NH4Ac and at a pH of 7.

3. Results and discussion.

3.1. The classification

All results of profile descriptions and chemical and physical analyses are displayed in appendix 4. With the results of the analyses it became possible to classify all the soils according to the system of the Soil Taxonomy and the proposal of ICOMAND. The area has an udic moisture regime (except for COC 25 where the moisture regime is aquic) and an isohyperthermic temperature regime.

The classification is at follows:

NEG 308 : In the Soil Taxonomy the Andic suborder requires a bulk density which is less than 0.85 g per cubic centimeter (requirement not met) or 60% or more pyroclastic material (probably not met). So NEG 308 will fall in the tropic suborder and be classified as a Typic Dystropepts.

In ICOMAND more then 5% volcanic glass is required at the high value for acid-oxalate-extractable aluminum plus 1/2 acid-oxalate-extractable iron. Dark colors (2.5 Y 3/0) of the parent material and the development of andic properties justify the assumption that more than 5% volcanic glass is available. NEG 308 will then be classified as a Thaptic Melanudand.

GP 16 : This soil meets the requirements of an Andept and will be classified as a Hydric Dystrandept.

In ICOMAND the soil will be classified as a Pachic Hapludand due to the high organic carbon contents and the dark colors.

GC 26 : GP 16 and GC 26 are not differentiated by Soil Taxonomy and therefore is this soil also classified as a Hydric Dystrandept.

In ICOMAND the lower content of organic carbon is expressed in the great group and the soil will be classified as a Thaptic Hapludand.

COC 5 : All characteristics except for the light colors are typical for a Dystrandept. COC 5 will therefore be classified as an Entic Dystrandept.

According to ICOMAND the soil has not enough andic properties to fall in the soil order of the Andisols. Nevertheless are the andic properties expressed in the subgroup resulting in an Andic Dystropept.

COC 6 : Following the classification of Soil Taxonomy this soil is also classified as NEG 308 as a Typic Dystropept.

According to ICOMAND NEG 308 and COC 6 are differentiated due to the fact that COC 6 does not meet all the requirements for the Andisols. The requirements of the andic subgroup are also not met and therefore ICOMAND does not change the classification which will remain a Typic Dystropept.

COC 8 : The classification according to Soil Taxonomy follows the same way as the previous profile and NEG 308 also resulting in a Typic Dystropept.

Following ICOMAND COC 5 and COC 8 belong to the same subgroup Andic Dystropept.

COC 24 : The topsoil gives all the indications necessary for the dominance of amorphous materials in the exchange complex. The bulk density restricts the classification as an Andept and the classification according to Soil Taxonomy will result in a Fluventic Dystropept.

Following ICOMAND COC 8 is classified like COC 5 and COC 8 as an Andic Dystropept.

COC 25 : Due to bad drainage caused by extreme compaction of the upper 30 cm the soil is classified as an Aquic Dystropept.

The soil meets the requirements of the andic subgroup. ICOMAND does not say which subgroup is keyed out first. Most likely is to key out the aquic subgroup first and therefore the classification remains the same, Aquic Dystropept.

RJZ 22, RJZ 24 and RJZ 25 : These soils differ mainly in the B-horizon. The classification is mainly based on the topsoil as long as the subsurface horizon is no other than cambic. The classification according to the Soil Taxonomy is for all these soils a Hydric Dystrandept.

These soils are classified as Typic Hapludand using the keys as proposed by ICOMAND.

EG 2 : According to Soil Taxonomy classified as a Humoxic Tropohumult.

No andic properties are present and therefore the classification according to ICOMAND does not change.

EG 3 : Although quite different from NEG 308, COC 6 and COC 8 the soil is also classified as a Typic Dystropept by the Soil Taxonomy.

ICOMAND differentiates this soil from NEG 308 and COC 8 due to the fact that the requirements of an andic subgroup are not met and the classification will remain a Typic Dystropept.

EG 4 : Classification leads to an Oxic Humitropept.

The requirements of an andic subgroup are met and EG 4 is classified as an Andic Humitropept.

For the soils in Cocori mineralogical analyses have to be carried out to decide. In the past many mineralogical studies have been carried out (Andriesse and Muller, 1973; Martini, 1969 etc) and in all studies enough (more than 5%) volcanic glass is

found. The problem is that these studies are carried out in the cordillera central close to the volcanoes and 40 km south from Cocori. The analysis of one sample of the Cocori area at the department of soil science and geology at the Agricultural University in Wageningen showed that there was almost no volcanic glass (A. Nieuwehuysse, pers. ann.). The sample was taken in an older part of the Cocori area but can give an indication. On the other hand it is visible that andic properties are developing in the A-horizon and therefore the parent material should contain volcanic glass.

Looking at table 1 the classifications are summarized. All Andepts are classified by ICOMAND in the new soil order of the Andisols. NEB 308 which has almost all the morphological characteristics of the volcanic ash soils is also keyed out as an Andisol. Many soils, which own some andic properties but not enough to fall in the Andisols are characterized in an andic subgroup.

Table 1: Classifications of the soils according to the Soil Taxonomy and the proposal of ICOMAND.

	Soil Taxonomy	ICOMAND
NEG 308	Typic Dystropept	Thaptic Udivitrand
GP 16	Hydric Dystrandept	Thaptic Melanudand
GC 26	Hydric Dystrandept	Thaptic Hapludand
COC 5	Entic Dystrandept	Andic Dystropept
COC 6	Typic Dystropept	Typic Dystropept
COC 8	Typic Dystropept	Andic Dystropept
COC 24	Fluventic Dystropept	Andic Dystropept
COC 25	Aquic Dystropept	Aquic Dystropept
RJZ 22	Hydric Dystrandept	Typic Hapludand
RJZ 24	Hydric Dystrandept	Typic Hapludand
RJZ 25	Hydric Dystrandept	Typic Hapludand
EG 2	Humoxic Tropohumult	Humoxic Tropohumult
EG 3	Typic Dystropept	Typic Dystropept
EG 4	Oxic Humitropept	Andic Humitropept

3.2. Physical and chemical description of the soils.

3.2.1. Inceptisols of the Cocori area.

The profiles with codes starting with COC are included this group. These soils can be described as moderate to well-drained young soils with a thin very dark grayish brown loam A-horizon overlying a dark yellowish brown, sandy loam to loamy sand B-horizon.

The morphological description of the thin A-horizon suggests the presence of andic properties. Some of the analyses support this first impression. The bulk density (0.70 g/g) is low, even within the criteria for andic properties according to ICOMAND (1988). Wesley (cited by Warkentin, 1980) indicates on the Cassagrande plasticity chart an area typical for andisols, in which these samples fall too. A small or positive difference between the pH-H2O and the pH-KCl indicates a high variable charge (Scheffer and Schaftschabel, 1984) typical for andisols and has been observed in the wet samples of the A-horizons. In COC 8 and COC 24 even a phosphate retention higher then the criteria (>85%) is present. Other analysis do not confirm the andic properties of the A-horizons. For the classification the low amount of acid-oxalate-extractable aluminum and iron is decisive. For the profiles COC 5 and COC 6 the phosphate retention confirms this judgment. The low pH-NaF (<10) and the low water content at pF 4.2 also support the classification, but can be explained by the coarse texture of these soils. It should be remarked that even if the A-horizon should fulfil the criteria of andic properties the thickness of 35 cm is not reached.

Now looking at the B-horizon COC 5 fulfills the criteria for andic properties. The relatively fine texture can be an

explanation for the fact that this horizon fulfills the requirements off andic properties. For the other samples the bulk density is too high (>0.8 g/g) and the amount of acid oxalate extractable aluminum and iron too low to fulfil the criteria for andic properties.

3.2.2. Andisols of the Rio Jimenez and Guapiles area.

All the profiles with the following codes include this group: NEG 308, GP 16, GC 26, RJZ 22, RJZ 24 and RJZ 25. The soils can be described as well-drained young soils with a thick very dark loam A-horizon, overlying, if present, a dark to yellowish brown sandy loam B-horizon, over a sand often bouldery and very stony C-horizon.

All these soils have a A-horizon that fulfills the criteria for andic properties. The positions in the Cassagrande plasticity chard correspond more or less with the area indicated by Wesley (1973), although in many cases the liquid limit is very low. The pH-NaF is high and supports therefore the classification. For the soils around Guapiles the pH-KCl is higher then the pH-H2O for the undried samples. This matches the expectation of the high variable charge for the volcanic ash soils. On the other hand the soils of Rio Jimenez also fulfill the criteria for andic properties but for these soils the pH-H2O is higher then the pH-KCl. Main difference between the soils out of Rio Jimenez and the others is the low content of organic carbon.

For this group of soils there are quite some differences in development of the B-horizon. In the profiles NEG 308 and RJZ 22 the B-horizon is fully absent. On the other hand possesses GC 26 a very deep and well developed B-horizon and RJZ 25 a B-horizon with andic properties. In most cases the bulk density is the

limiting attribute for andic properties and is strongly correlated with the texture. High variable charge occurs in the profiles of Rio Jimenez, a high pH-NaF (11.3) in GP 16 and a low bulk density in RJZ 25 indicating the heterogeneity of the B-horizons.

The C-horizon although almost pure sand still contains a high phosphate retention, a high bulk density (1.3 g/g) and a low content of variable charge.

3.2.3. Soils of the Neguev.

The soils with codes Eg 2, Eg 3 and Eg 4 include this group. The soils can be described as well-drained relatively stronger developed soils with a thin dark clay A-horizon overlying a dark firm clay loam B-horizon.

Thixotropy in the B-horizons of Eg 3 and Eg 4, the rather high phosphate retention (70 %), the high variable charge in Eg 3 and the low bulk density (0.8 g/g) give the impression of andic properties. The morphological characteristics of these soils do not point to andic properties at all. The soils are light colored with hues dry of 7.5 YR, heavy textured and highly weathered with low pH values (pH-H2O = 4.7) that do not match the characteristics of andic properties. Due to the low sum of acid oxalate extractable aluminum plus half the acid oxalate extractable iron and the low phosphate retention these soils do not meet the requirements for andic properties.

3.3. A field criterion.

As already noticed by Leamy (in ICOMAND,1986) many of the analyses necessary for the classification of andisols can be locally replaced by field criteria. In the literature many field

criteria are described for the different analyses (Alvarado and Fuol, 1985; Holmgren and Kimble, 1984; Maeda and Sona, 1986 and Tnoue, 1986). In this investigation I tried to find a correlation between a simple analysis or a morphological characteristic and the criteria for andic properties for the area of investigation. Comparing the values of the different measurements for andic and non-andic soil material with a F-test a significant difference can be demonstrated (table 2). The high F values for acid oxalate extractable aluminum can be explained by the importance of this characteristic in the classification. High F values for pH-NaF and KOH extractable aluminum gives hope in the search for a field criterium. A difference even if it is significant does not always mean that it can be used as a criteria for classification. To calculate the critical value, which can be used for separating the andic and non-andic soil materials, the following formulas are used:

If AVGn > AVGa then: K = ((AVGa + STDa) + (AVGn - STDn))/2
if AVGn < AVGn then: K = ((AVGn + STDn) + (AVGa - STDa))/2
in which: AVGn = Average for non-andic material,
AVGa = Average for andic material,
STDn = Standard deviation for non-andic material,
STDa = Standard deviation for andic material,
K = Critical value.

In table 3 these critical values are given. The critical values are tested by a count of misclassification for non-andic and andic material separately. This can be converted to a percentage of mis-classification based on the 53 different soil materials investigated in this investigation. Very good results are scored

for the pH-NaF after 60 minutes. Looking for criteria to be used in the field KOH extractable Al performs very well with an error of 13%. Still it should be said that following up the morphological descriptions of the andic material the error can be limited. Looking at the literature and with some knowledge of the Atlantic zone and its soils the following list of characteristics is composed:

- sandy loam, loam or silt loam,
- weak structures, if the A-horizon is compacted, moderate structures can occur without loosing the andic properties,
- thixotropic,
- black, very dark brown or very dark grayish brown.

The error in the classification occurs mainly in the Cocori area, where it is difficult to identify the andic properties, using morphological criteria.

Table 2: Results of the F-test and descriptive statistics: carried out for andic versus non-andic soil material

			non-andic		andic	
		F	AVG	STD	AVG	STD
Pf 4.2 dry	(%)	14.7	19.0	9.3	31.4	8.9
wet	(%)	16.1	27.3	13.3	44.3	9.1
Bulk density	(g/g)	19.3	0.92	0.16	0.69	0.11
pH H2O wet		0.0	5.4	0.5	5.4	0.3
dry		4.2	4.7	0.5	5.2	0.4
paper		0.0	5.4	0.4	5.4	0.2
pH KCl wet		5.6	4.5	0.3	4.8	0.2
dry		2.6	4.6	0.5	4.9	0.2
pH NaF wet 2 min.		28.4	10.1	0.5	11.0	0.4
wet 60 min.		31.9	10.9	0.5	11.9	0.2
dry 2 min.		38.8	10.0	0.6	11.1	0.5
dry 60 min.		41.7	10.7	0.5	11.8	0.2
paper		12.4	9.3	0.4	9.9	0.4
Ac Ox Ex dry	Al	52.6	0.9	0.6	2.5	0.6
(%)	Fe	1.3	1.0	0.6	1.3	0.3
(Al + 0.5*Fe)		51.5	1.4	0.7	3.2	0.6
	Si	36.2	0.2	0.3	1.0	0.3
wet	Al	119.2	0.7	0.4	2.8	0.8
	Fe	1.3	0.8	0.4	1.0	0.5
(Al + 0.5*Fe)		120.1	1.1	0.5	3.3	0.7
	Si	45.8	0.2	0.3	1.1	0.3
P retention wet		35.3	71.5	13.0	95.4	4.2
(%) dry		16.3	50.9	16.5	72.5	10.3
Water content		9.8	54	18	75	16
KOH extractable Al						
wet		27.2	0.4	0.1	0.7	0.3
dry		28.3	0.5	0.2	0.9	0.1

F = Result F-test (0.99 confidence limit = 2.66)

AVG = Average.

STD = Standard deviation.

Table 3. Critical values and classification errors.

			K	En	Ea	E%
Pf 4.2	dry	(%)	25.4	12	3	28
	wet	(%)	37.9	10	2	23
Bulk density		(g/g)	0.79	8	3	21
pH H2O	wet					
	dry		5.0	6	3	17
	paper					
pH KCl	wet		4.7	11	2	25
	dry		4.9	11	4	28
pH NaF	wet	2 min.	10.6	6	2	15
	wet	60 min.	11.5	4	0	8
	dry	2 min.	10.5	6	1	13
	dry	60 min.	11.5	3	0	6
	paper		9.6	11	3	26
Ac Ox Ex	dry	Al	1.7	6	1	13
(%)		Fe	1.2	15	5	38
(Al + 0.5*Fe)			2.3	4	1	9
		Si	0.6	5	1	11
	wet	Al	1.6	4	1	9
		Fe	0.9	18	4	42
(Al + 0.5*Fe)			2.2	3	0	6
		Si	0.6	5	1	11
P retention	wet		87.8	3	7	19
(%)	dry		65.1	6	2	15
Water content			66	11	3	26
KOH extractable Al						
	wet		0.5	8	2	19
	dry		0.8	6	1	13

K = Critical value

En = Number of non-andic materials classified as andic out of a total of 41.

Ea = Number of andic materials classified as non-andic out of a total of 12.

3.4. Effect of compaction on andic properties.

In the Atlantic zone of Costa Rica most rain forest has already been cut. After the deforestation a large part of the area became grassland used for cattle production. As a result of heavy machinery during deforestation and cattle, compaction of the soil is a common feature. Compaction is indicated by mottling as a result of temporary waterlogging, by a stronger grade of aggregation and in many cases by an angular blocky structure. No relation between compaction and change in andic properties can be found and probably more processes have their effect on the change of andic properties in the topsoil.

The area used for annual crops is not directly effected by the weight of cattle, but lies open in burning sun and falling rain. This can also result in a change of the amorphous clay although the effect of degradation is hard to distinguish morphologicallly. In table 4 some morphological characteristics of the surface horizon are given.

All the profiles under grass have been compacted. Almost certainly this is mainly caused by cattle. Deforestation could have been relevant in the compaction process even before the area was covered with grass. This is demonstrated by compacted profiles which never have been under grass. It is hard to obtain information about the deforestation. Still this is necessary to complete the image of compaction in relation to deforestation, cattle breeding and soil type.

The effect of compaction on the change of andic properties in soils with amorphous clay is not clear. Uncompacted profiles cultivated with annual crops show a reduction of the andic properties in the surface horizon probably caused by the direct climatic influence on the surface horizon in the period when the

soil is not covered by crop or other vegetation. Degradation of the amorphous clays in the profiles under grass (which are compacted) can be caused by or related to the compaction but can also be fossil of the period before covering the soil with grass.

Table 4:

Morphological characteristics of the surface horizons.

Number	Crop	Comp.	Mottling	Structure Grade	Structure Type
NEG 309	Banana	none	none	moderate	sub-angular crumb
Gp 16	Grass	yes	few	moderate	angular
Gc 26	Sour-sop	slight	none	moderate	angular
Coc 5	Cacao	yes	common	moderate	angular
Coc 6	Sec. For.	yes	common	moderate	sub-angular
Coc 8	Prim. for	none	none	moderate	angular granular
Coc 24	Grass	yes	common	weak	angular
Coc 25	Grass	severe	common	moderate	angular
RJZ 22	Mixed	none	none	weak	sub-angular por. massive
RJZ 24	Mixed	none	none	moderate	sub-angular
RJZ 25	Corn	none	none	moderate	sub-angular
EG 2	Grass	yes	many	strong	angular
EG 3	Sec. For.	none	none	moderate	granular
EG 4	Grass	yes	common	strong	angular

4. Conclusions.

The new soil order andisol will include a large group of soils of the Atlantic zone in Costa Rica. The older mudflows even when they are thixotropic and the young soils out of the Cocori area are excluded. It must be mentioned that mineralogical examinations are necessary to complete the picture of these soils. In the case of the young sandy soils this can give the solution about the content of volcanic glass.

Many soils with andic propeties were not included in the subgroup of the Andepts. With the ICOMAND criteria these soils are classified in an andic subgroup. In the area of investigation the soils of the Cocori area and one out of the Neguev fall in an andic subgroup.

The new classification procedure as proposed by ICOMAND seems to give good results for this area. Still the question should be asked if the large number of complex analysis are necessary.

It is hard to find general field criteria for andic properties. The pH measured with NaF can give good results, especially if morphological criteria are also taken into account. The pH measured with NaF after 60 min. should exceed 10.6. The soils should be dark, have a texture of loamy sand or finer and should be thixotropic.

This investigation can not give an answer on the question if the andic properties have changed due to compaction. Much more of the history of the soils should be known.

BIBLIOGRAPHY

. ALVARADO, A. and S.W. BUOL. 1985. Field estimation of phosphate retention by andepts. Soil Sci. Soc. Am. J., Vol 49, pp. 911-914.

. ANDRIESSE, J.P., and A. MULLER. 1973. Mineralogical properties of two profiles of volcanic ash soil from Costa Rica. Turrialba Vol. 23, No 3, pp. 303-317.

. ASTM, 1981. Annual book of ASTM standards. American Society for Testing and Materials, Philadelphia.

. ESWARAN, H. 1981. Status report on the international committees. Soil Management Support Services of USDA, Soil Conservation Service, Washington.

. FAO-UNESCO, 1974. Map of the World, Vol. 1, Legend. Unesco, Paris.

. HOLMGREN, G.G.S., and J.M. KIMBLE. 1984. Field estimation of amorphous aluminum with 4M potassium hydroxide. Soil Sci. Soc. Am. J. , Vol 48, pp. 1378-1382.

. ICOMAND, 1986. International committee on the classification of andisols (ICOMAND), circular letter no. 8. by M.L. Leamy, Soil Bureau, DSIR, Private Bagg, Lower Hutt, New Zealand.

. ICOMAND, 1988. International committee on the classification of andisols (ICOMAND), circular letter no. 10. by M.L. Leamy, Soil Bureau, DSIR, Private Bagg, Lower Hutt, New Zealand.

. MARTINI, J.A. 1969. Geographic distribution and characteristics of volcanic ash soils in central america. Proceedings of the Panel on Volcanic Ash Soils in Latin America, Turrialba, Costa Rica, Paper A5.

. MAEDA, K., and K. SOMA. 1986. Physical properties. in: Wada, K., (ed.). Ando Soils in Japan. Kyushu University Press. Japan. pp. 99-111.

. MUNSELL, 1971. Soil Color Charts. Munsell Color Company, Baltimore.

. REEUWIJK, L.P. van, 1986. Procedures for soil analysis, ISRIC, Technical Paper 9.

. SCHEFFER, H.C., and SCHACHTSCHABEL, P. 1984. Lehrbuch der bodenkunde, 11. neu bearbeitete Auflage, Ferdinand Enke Verlag Stuttgart.

. SWINDALE, L. 1969. Properties of volcanic ash soils. Proceedings of the Panel on Volcanic Ash Soils in Latin America, Turrialba, Costa Rica, Paper B10.
. TNOUE, K. 1986. Chemical properties. in: Wada, K., (ed.). Ando Soils in Japan. Kyushu University Press. Japan. pp. 69-98.
. U.S. SOIL SURVEY STAFF, 1975. Soil Taxonomy, a Basic System of Soil Classification for Making and Interpreting Soil Surveys. Soil Conservation Service, U.S. Dept. Agric. Agric. handbook 436, Washington.
. WARKENTIN, B.P., Maeda, T. 1980. Physical and mechanical characteristics of andisols. In:THENG, B.K.G. (Editor) 1980. Soils with variable charge. New Zealand Society of Soil Science, Lower Hutt, pp 281-301.
. WESLEY, L.D. 1973. Some basic engineering properties of halloysite and allophane clays in Java, Indonesia. Geotechnique, 23: 471-94.
. WRIGHT, A. C. S. 1964. The "Andosols" or "Humic Allophane" soils of South America. World Soil Resources Report 14:9-22.

Appendix 1: The area of investigation.

Appendix 2: ANDIC SOIL PROPERTIES (ICOMAND, 1988)

To have andic soil properties, the soil material must meet one or more of the following three requirements:

1. a. Acid oxalate extractable aluminum plus 1/2 acid-oxalate-extractable iron is 2.0% or more, and
   b. Bulk density of the <2 mm fraction, measured at 1/3 bar water retention, is 0.90 g/cm3 or less, and
   c. Phosphate retention is more than 85%; or
2. a. More than 60% by volume of the whole soil is volcaniclastic material coarser than 2 mm, and
   b. Acid oxalate extractable aluminum plus 1/2 acid-oxalate-extractable iron is 0.40% or more in the <2 mm fraction, and
   c. Phosphate retention is more than 25%; or
3. The 0.02 - 2.0 mm fraction is at least 30% of the <2 mm fraction and meets one of the following three requirements:
   a. If the <2 mm fraction has phosphate retention of more than 25% and has acid-oxalate-extractable aluminum plus 1/2 acid oxalate extractable iron of 0.40% or more, there is at least 30% volcanic glass in the 0.02 - 2.0 mm fraction, or
   b. If the <2 mm fraction has acid-oxalate-extractable aluminum plus 1/2 acid-oxalate-extractable iron of 2.0% or more, there is at least 5% volcanic glass in the 0.02 - 2.0 mm fraction, or
   c. If the <2 mm fraction has acid-oxalate-extractable aluminum plus 1/2 acid-oxalate-extractable iron of 2.0% or more, there is at least a proportional content of volcanic glass in the 0.02 - 2.0 mm fraction between 30 and 5 percent.

Appendix 3: Brief profile descriptions.

NEG 308

Well-drained soil with a very thin, very dark, sandy loam surface layer overlying a very dark, loamy sand, massive porous, thixotropic A-horizon. At about 60 cm a very dark sand C-horizon was seen.

GP 16

Well-drained soil with a thin, compacted, black, silt loam, surface layer overlying a thick, black, weak fine subangular blocky, thixotropic, porous, slightly gravelly and slightly stony loam A-horizon. At about 70 cm a dark, massive porous, firm, thixotropic, gravelly, stony bouldery loamy sand B-horizon was seen.

GC 26

Well-drained soil with a thick, very dark, weak subangular blocky with crumb, thixotropic, porous, slightly gravelly loam A-horizon overlying at 90 cm a dark, loamy sand to sandy loam, weak structured to massive porous, friable, thixotropic B-horizon.

COC 5

Moderately well-drained soil with a thin, compacted, very dark, loam, weak angular blocky, slightly thixotropic, porous A-horizon overlying a dark, loam, porous massive, very thixotropic B-horizon.

COC 6

Moderately well-drained soil with a thin, compacted, very dark, loam surface layer overlying a dark, sandy loam, thixotropic A-horizon and at 30 cm a very dark with gley, loamy sand, porous massive, friable, thixotropic B-horizon and at 80 cm a very dark, loose sand C-horizon.

COC 8

Moderately well-drained soil with a thin, very dark, loam, moderate angular blocky, porous A-horizon overlying a dark, loam to sandy loam, weak subangular blocky, thixotropic, porous B-horizon with some gley and a very dark loose sand C-horizon.

COC 24

Well-drained soil with a very thin, compacted, very dark, loam, weak angular blocky, porous A-horizon overlying a yellowish brown, loam to silt loam with around 45 cm a thin layer loamy sand, moderate very fine subangular blocky to massive porous with crumb, thixotropic B-horizon with gley deeper than 70 cm.

COC 25

Imperfectly drained soil with a thin, compacted, very dark, loam, moderate angular blocky A-horizon overlying a brown to yellowish brown with grey parts, weak angular blocky to massive porous, slightly thixotropic B-horizon with many gley.

RJZ 22

Well-drained soil with a thick very dark, sandy loam, weak subangular blocky to strong very fine crumb, very thixotropic A-horizon overlying at 64 cm a very dark, gravelly sand, massive C-horizon.

RJZ 24

Well-drained soil with a thick very dark, loam, moderate subangular blocky with crumb, very thixotropic A-horizon overlying at 50 cm a light colored, clay loam, moderate subangular blocky, very thixotropic B-horizon and at 110 cm a dark loose sand C-horizon.

RJZ 25

Well-drained soil with a thick, very dark, silty clay loam, moderate subangular blocky with crumb, very thixotropic, porous A-horizon overlying at 56 cm a light colored, sandy loam, massive porous, very thixotropic B-horizon, a dark, sand, massive, very thixotropic C-horizon and at 100 cm a light, clay loam, thixotropic 2C-horizon with gley.

EG 2

Well-drained soil with a thin, compacted, dark, clay, strong angular blocky, porous A-horizon overlying a very thick, dark, clay. moderate angular blocky with crumb, firm, porous B-horizon.

EG 3

Well-drained soil with a very thin, dark silty clay loam, moderate granular A-horizon overlying a dark, clay loam, weak crumb, thixotropic, porous B-horizon and at 75 cm a dark, loam, massive porous, very firm, very thixotropic C-horizon.

EB 4

Well-drained soil with a moderately thick, compacted, dark, clay, moderate angular blocky, thixotropic, porous A-horizon overlying at 30 cm a dark, very stony clay loam, weak crumb, thixotropic, porous B-horizon.

Appendix 4. **Profile Descriptions according to the guidelines for profile description (FAO, 1977).**

I Information on the site

a. Profile Number: NEG 308.
b. Soil Name: Suelo Dos Novillos.
c. Higher Category Classification:
Soil Taxonomy: Typic Dystropept.
ICOMAND: Thaptic Udivitrand.
d. Date of Examination: 21 May 1987.
e. Author: Jetse Stoorvogel.
f. Location: In a field of bananas in Hacienda Bremen, close to the confluence of the Parismina river with the Dos Novillos river, Limon province, map sheet of Guacimo 3446 I, 582.4 W; 245.8 N, Costa Rica.
g. Elevation: 20 meters.
h. Land form:
i. physiographic position: river terrace from the Dos Novillos river.
ii. surrounding land form: flat.
iii. microtopography: nil.
i. Slope on which profile is sited: flat (0%).
j. Land-use: banana.
k. Climate: Total annual rainfall is about 4500 mm. and the mean annual temperature is about 23.5C. The week before this description was sunny and rainy.

II General Information on the Soil

a. Parent material: Alluvial deposits of mostly volcanic sand and gravel.
b. Drainage: Class 4 - well drained.
c. Moisture conditions in profile: All the profile is moist.
d. Depth of groundwater table: deeper than the profile.
e. Presence of surface stones, rock outcrops: none.
f. Evidence of erosion: none.
g. Evidence of compaction: none.
h. Human influence: pollution with plastic bags and rope, used in the culture of bananas.
i. Soil fauna: not seen.

III Profile Description

Ah 0 - 5 cm

Very dark gray (10 YR 3/1) moist and dark brown (10 YR 4/3) dry, sandy loam; moderate very fine subangular blocky and crumb; slightly sticky, slightly plastic, very friable moist, slightly thixotropic wet; few continuous tubular pores; abundant pores of various sizes; clear smooth boundary; pH 5.2.

Au 5 - 47/70 cm

Very dark grayish brown (10 YR 3/2) moist and dark grayish brown (10 YR 4/2) dry, loamy sand; massive porous structure; slightly sticky, slightly plastic, very friable moist, thixotropic wet; many very fine, fine and medium continuous tubular pores; frequent roots of various sizes; clear irregular boundary; pH 5.4.

C 47/70 - 100 cm

Very dark gray (2.5 Y 3/0) moist and very dark gray (10 YR 3/1) dry, sand; structureless; non-sticky, non-plastic, loose moist; pH 5.9.

IV Chemical and physical analysis

Profile number:	NEG 308			
Depth of horizon (cm)			5	47/70	100
Physical analyses					
Bulk density	(g/cc)		0.93	0.90	1.31
Liquid Limit	(%)	dry	52	44	--
		wet	108	262	--
Plasticity Index	(%)	dry	7	--	--
		wet	60	212	--
@ during sampling	(%)		46	46	8
@ at pF4.2	(%)	dry	14.5	12.4	1.6
		wet	21.7	24.5	2.3
texture:	sand	(%)	50	56	94
	loam	(%)	43	37	1
	clay	(%)	7	7	5
Chemical analyses					
pH-H2O		dry	5.2	5.4	5.9
		wet	4.6	4.7	5.0
pH-H2O, paper.			5.7	5.9	6.7
pH-KCl		dry	4.6	4.8	5.1
		wet	4.8	5.1	5.0
pH-NaF after 2 min.		dry	10.9	11.4	9.7
		wet	10.6	11.3	9.3
pH-NaF after 60 min.		dry	11.7	12.1	10.8
		wet	11.5	11.9	10.5
pH-NaF with paper.			9.0	10.0	9.0
phosphate ret.	(%)	dry	67.0	84.4	31.3
		wet	49.8	62.5	11.9
Acid oxalate extractable					
	Al	dry	1.6	1.8	0.5
		wet	1.4	2.0	0.4
	Fe	dry	0.7	0.7	0.5
		wet	0.6	0.7	0.4
	Si	dry	0.7	0.9	0.2
		wet	0.7	1.1	0.3
KOH extractable Al		dry	0.5	0.6	0.2
		wet	0.8	1.3	0.2
Organic matter	(%)		3.68	3.41	0.75
CEC	(meq/100g)		22.36	17.16	6.24
Ca	(meq/100g)		4.50	2.25	0.75
Mg	(meq/100g)		2.38	0.56	0.28
K	(meq/100g)		1.03	0.61	0.51

I Information on the site

a. Profile Number: Gp 16.
b. Soil Name: Suelo Corinto.
c. Higher Category Classification:
Soil taxonomy: Hydric Dystrandept.
ICOMAND: Thaptic Melanudand.
d. Date of Examination: 17 February 1987.
e. Author: Egbert Spaans and Jetse Stoorvogel.
f. Location: 100 meters west of the river Costa Rica, 500 meters north of the highway Limon-San José, 7 km. west of Gu piles, Limon province, map sheet of Gu piles 3446 IV, 551.7 W; 244.6 N, Costa Rica.
g. Elevation: 227 meters.
h. Land form:
i. physiographic position: Lowest part of the talus from the vulcan Turrialba, very close to a few big wilded river systems.
ii. surrounding land form: flat.
iii. microtopography: nil.
i. Slope on which profile is sited: flat (0%).
j. Land-use: Grassland.
k. Climate: Total annual rainfall is about 4500 mm. and the mean annual temperature is about 23.5C. The week before this description was sunny and dry.

II General Information on the Soil

a. Parent material: Alluvial deposits of mostly volcanic sand, gravel and stones.
b. Drainage: Class 4 - well drained.
c. Moisture conditions in profile: All the profile is moist.
d. Depth of groundwater table: Deeper than the profile.
e. Presence of surface stones, rock outcrops: Very few stones.
f. Evidence of erosion: none.
g. Evidence of compaction: Compacted in the upper 7 cm.
h. Human influence: none.
i. Soil fauna: earthworms.

III Profile Description

Ah1 0 - 7 cm

Black (10 YR 2/1) moist and dark brown (10 YR 3/3) dry, few, small, distinct, sharp, brown mottles; silt loam; moderate very fine angular blocky; slightly sticky, slightly plastic, very friable moist, slightly thixotropic wet; frequent very fine continuous pores; frequent very fine and fine roots; abrupt smooth boundary; pH 4.7.

Ah2 7 - 72 cm

Black (10 YR 2/1) moist and very dark grayish brown (10 YR 3/2) dry, slightly gravelly, slightly stony loam; weak fine subangular blocky; slightly sticky, slightly plastic, friable moist, thixotropic wet; common fine and many very fine continuous tubular pores; few rounded fresh gravel and few rounded fresh stones; frequent fine roots; abrupt smooth boundary; pH 5.7.

Bu1 72 - 124 cm

Dark brown (10 YR 4/3) moist and dark brown (10 YR 4/3) dry, gravelly, stony, bouldery, loamy sand; massive porous structure; slightly sticky, slightly plastic, firm moist, thixotropic wet; many very fine and few fine continuous tubular pores; frequent rounded strongly weathered stones and few rounded strongly weathered boulders; frequent fine roots; pH 6.0.

IV Chemical and physical analysis

Profile number: GP 16				
Depth of horizon (cm)		7	72	124
Physical analyses				
Bulk density (g/cc)		0.64	0.68	1.11
Liquid Limit (%)	dry	106	78	--
	wet	277	175	489
Plasticity Index (%)	dry	1	--	--
	wet	160	99	--
@ during sampling (%)		81	56	11
@ at pF4.2 (%)	dry	53.3	33.9	21.8
	wet	61.5	49.1	30.3
texture: sand (%)		73	69	--
loam (%)		18	24	--
clay (%)		9	7	--
Chemical analyses				
pH-H2O	dry	4.7	5.7	6.0
	wet	4.7	5.0	5.4
pH-H2O, paper.		5.3	5.3	5.7
pH-KCl	dry	4.5	4.8	5.3
	wet	4.6	5.3	5.9
pH-NaF after 2 min.	dry	11.4	11.5	11.3
	wet	11.3	11.8	11.1
pH-NaF after 60 min.	dry	12.1	12.4	12.2
	wet	11.9	12.2	11.9
pH-NaF with paper.		10.5	10.0	10.0
phosphate ret. (%)	dry	96.5	99.9	95.3
	wet	72.0	96.2	80.3
Acid oxalate extractable				
Al	dry	2.4	3.7	3.5
	wet	2.4	4.2	2.4
Fe	dry	1.5	1.7	0.5
	wet	0.6	1.1	0.6
Si	dry	0.8	1.3	1.8
	wet	0.9	1.6	1.8
KOH extractable Al	dry	0.9	1.0	0.8
	wet	1.2	1.1	0.8
Organic matter (%)		18.97	8.60	--
CEC (meq/100g)		37.63	36.04	--
Ca (meq/100g)		2.25	0.94	--
Mg (meq/100g)		1.16	0.28	--
K (meq/100g)		0.48	0.13	--

I Information on the site

a. Profile Number: GC 26.
b. Soil Name: Suelo Cristina.
c. Higher Category Classification:
Soil taxonomy: Hydric Dystrandept.
ICOMAND: Thaptic Hapludand.
d. Date of Examination: 17 May 1987.
e. Author: Jetse Stoorvogel.
f. Location: 1 km. north of Jimenez, 20 meters west of the road, Limon province, map sheet of Gu cimo 3446 I, 565.6 W; 245.8 N, Costa Rica.
g. Elevation: circa 200 meters.
h. Land form:
i. physiographic position: Lowest part of the talus from the vulcan Turrialba.
ii. surrounding land form: flat.
iii. microtopography: nil.
i. Slope on which profile is sited: flat (0%).
j. Land-use: For two years there was pine-apple, now they planted trees of sour-sop (guanabana).
k. Climate: Total annual rainfall is about 4500 mm. and the mean annual temperature is about 23.5C. The week before this description was very rainy.

II General Information on the Soil

a. Parent material: Alluvial deposits of mostly volcanic sand.
b. Drainage: Class 4 - well drained.
c. Moisture conditions in profile: All the profile is very moist.
d. Depth of groundwater table: Deeper than the profile.
e. Presence of surface stones, rock outcrops: none.
f. Evidence of erosion: none.
g. Evidence of compaction: none.
h. Human influence: none.
i. Soil fauna: ants and various types of larvas.

III Profile Description

Ah1 0 - 10 cm
Very dark brown (10 YR 2/2) moist and dark brown (10 YR 3/3) dry, loam; moderate very fine angular blocky; slightly sticky, slightly plastic, very friable moist, thixotropic wet; common very fine and few fine continuous tubular pores; common very fine roots; abrupt smooth boundary; pH 5.9.

Ah2 10 - 89 cm
Very dark brown (10 YR 2/3) moist and dark brown (10 YR 3/3) dry, slightly gravelly loam; weak very fine subangular blocky and crumb; slightly sticky, slightly plastic, very friable moist, thixotropic wet; many very fine and common fine continuous tubular pores; very few angular fresh gravel; few very fine and few fine roots; clear smooth boundary; pH 5.8.

Bu1 89 - 135 cm
Dark yellowish brown (10 YR 4/4) moist and light olive brown (10 YR 5/4) dry, loamy sand; weak very fine subangular blocky and crumb; slightly sticky, slightly plastic, friable moist, thixotropic wet; many very fine continuous tubular pores; few very fine roots; clear smooth boundary; pH 6.3.

Bu2 135 - 180 cm
Dark yellowish brown (10 YR 3/4) moist and light olive brown (10 YR 5/4) dry, common fine distinct sharp red-brown mottles; sandy loam; massive porous; slightly sticky, slightly plastic, friable moist, thixotropic wet; many very fine continuous tubular pores; very few large soft spherical brown ironstone nodules; few very fine roots; pH 6.2.

IV Chemical and physical analysis

Profile number:	GC 26				
Depth of horizon (cm)			10	89	135	180
Physical analyses						
Bulk density	(g/cc)		0.59	0.72	1.11	1.02
Liquid Limit	(%)	dry	---	61	52	---
		wet	105	78	49	---
Plasticity Index	(%)	dry	---	---	7	---
		wet	14	14	7	---
@ during sampling	(%)		86	67	43	46
@ at pF4.2	(%)	dry	27.0	24.2	26.1	13.4
		wet	42.4	38.3	30.8	19.9
texture:	sand	(%)	58	52	46	60
	loam	(%)	35	39	37	29
	clay	(%)	7	9	17	11
Chemical analyses						
pH-H2O		dry	5.9	5.8	6.3	6.2
		wet	4.6	5.0	4.6	6.1
pH-H2O, paper.			5.7	5.9	5.9	---
pH-KCl		dry	5.3	4.8	4.4	5.0
		wet	5.7	5.0	5.3	6.1
pH-NaF after 2 min.		dry	10.5	10.5	10.0	10.5
		wet	10.2	10.0	10.3	10.5
pH-NaF after 60 min.		dry	11.5	12.2	10.8	11.4
		wet	11.2	11.9	10.9	10.3
pH-NaF with paper.			9.5	9.0	10.0	---
phosphate ret.	(%)	dry	82.2	92.2	65.8	59.9
		wet	63.7	73.7	35.6	39.4
Acid oxalate extractable						
	Al	dry	1.8	2.9	0.6	1.4
		wet	1.8	2.6	0.4	0.8
	Fe	dry	0.9	1.5	0.9	1.8
		wet	1.0	1.2	0.9	1.0
	Si	dry	0.6	1.1	0.3	0.9
		wet	0.7	1.1	0.2	0.4
KOH extractable Al		dry	0.3	0.6	0.3	0.5
		wet	0.6	1.1	0.3	0.4
Organic matter	(%)		13.40	5.51	0.26	0.52
CEC	(meq/100g)		39.52	33.80	27.04	18.20
Ca	(meq/100g)		21.88	6.44	13.13	8.13
Mg	(meq/100g)		6.00	1.88	3.38	2.38
K	(meq/100g)		1.54	1.80	1.03	0.67

I Information on the site

a. Profile Number: COC 5.
b. Soil Name:
c. Higher Category Classification:
   Soil taxonomy: Entic Dystrandept.
   ICOMAND: Andic Dystrandept.
d. Date of Examination: 29 February 1987.
e. Author: André Nieuwenhuyse and Gerald Baltissen.
f. Location: 400 meters north of the river Penitencia, 1 km west of the road to Cocori, 15 km. north of Cariari, Limon province, Costa Rica.
g. Elevation: less than 20 meters.
h. Land form:
   i. physiographic position: alluvial plain.
   ii. surrounding land form: undulating.
   iii. microtopography: nil.
i. Slope on which profile is sited: halfway a 2%-slope.
j. Land-use: between 1975 and 1980 the area is deforestated, after which it has been used for corn, secondary forest and now cacao.
k. Climate: Total annual rainfall is about 4500 mm. and the mean annual temperature is about 23.5 C. The week before this description was sunny and dry.

II General Information on the Soil

a. Parent material: Alluvial deposits of mostly volcanic sand.
b. Drainage: Class 3 - moderately well drained.
c. Moisture conditions in profile: moist until 90 cm. deeper than 90 cm. the soil is wet.
d. Depth of groundwater table: 100 cm.
e. Presence of surface stones, rock outcrops: none.
f. Evidence of erosion: none.
g. Evidence of compaction: The upper 5 cm are compacted, angular blocky structure and mottles by oxidation and reduction.
h. Human influence: none.
i. Soil fauna: earthworms, ants, termites, mouses and rats.

III Profile description

Ag 0 - 5 cm
Very dark grayish brown (10 YR 3/2) moist and dark brown (10 YR 4/3) dry, common fine distinct red and gray mottles; loam; weak very fine angular blocky; slightly sticky, slightly plastic, friable moist, slightly thixotropic wet; common very fine and few medium pores; common fine and medium roots; clear smooth boundary; pH 5.1.

AB 5 - 15 cm
Dark brown (10 YR 4/3) moist and dark yellowish brown (10 YR 4/4) dry, loam; porous massive to weak fine subangular blocky; slightly sticky, slightly plastic, very friable moist, slightly thixotropic wet; many very fine and few medium pores; common fine and medium roots; clear wavy boundary; pH 5.0.

Bw 15 - 32 cm
Dark yellowish brown (10 YR 4/6) moist and yellowish brown (10 YR 5/4) dry, loam; porous massive to weak angular blocky; slightly sticky, slightly plastic, very friable moist, very thixotropic wet; many very fine and common fine pores; few fine and medium roots; abrupt smooth boundary; pH 5.5.

BC1g 32 - 48 cm
Yellowish brown (10 YR 5/4) moist and yellowish brown (10 YR 5/4) dry, many medium distinct gray and orange mottles; loam; porous massive to weak angular blocky; sticky, plastic, very friable moist, very thixotropic wet; many very fine and common fine continuous tubular pores; very few small soft irregular red ironstone nodules; few fine roots; abrupt smooth boundary; pH 5.7.

BC2g 48 - 63 cm
Dark brown (10 YR 3/3) moist and yellowish brown (10 YR 5/4) dry, common medium faint gray and orange mottles; sandy loam; weak fine granular and angular blocky to massive porous; slightly sticky, slightly plastic, friable moist, very thixotropic wet; many very fine and fine pores; few fine roots; pH 5.9.

IV Chemical and physical analysis

Profile number:	COC 5				
Depth of horizon (cm)		5	15	32	48	63
Physical analyses						
Bulk density (g/cc)		0.68	0.70	0.65	0.77	0.91
Liquid Limit (%)	dry	64	72	63	54	--
	wet	121	104	99	75	42
Plasticity Index (%)	dry	1	6	4	0	--
	wet	31	26	18	17	--
@ during sampling (%)		88	87	100	78	57
@ at pF4.2 (%)	dry	28.6	26.1	23.7	17.8	9.3
	wet	35.3	38.5	49.3	30.6	15.5
texture: sand (%)		38	40	28	16	66
loam (%)		47	45	55	67	23
clay (%)		15	15	17	17	11
Chemical analyses						
pH-H2O	dry	5.1	5.0	5.5	5.7	5.9
	wet	4.4	4.5	4.6	4.7	4.6
pH-H2O, paper.		5.3	5.5	5.3	5.3	5.3
pH-KCl	dry	4.5	4.4	4.5	4.5	4.6
	wet	4.5	4.8	4.5	4.5	4.6
pH-NaF after 2 min.	dry	9.8	10.5	10.4	11.1	10.6
	wet	9.3	10.4	10.7	10.8	10.3
pH-NaF after 60 min.	dry	10.5	11.4	11.8	11.9	11.3
	wet	10.0	11.2	11.6	11.7	11.1
pH-NaF with paper.		9.5	9.5	9.5	10.0	9.0
phosphate ret. (%)	dry	69.2	79.4	86.0	83.8	59.9
	wet	47.1	62.2	65.2	80.3	46.5
Acid oxalate extractable						
Al	dry	0.7	0.7	1.0	0.8	0.4
	wet	0.7	0.9	1.2	1.0	0.6
Fe	dry	1.4	1.3	2.1	1.7	1.1
	wet	1.1	1.8	2.5	2.0	1.0
Si	dry	0.1	0.2	0.2	0.2	0.2
	wet	0.2	0.2	0.3	0.3	0.2
KOH extractable Al	dry	0.3	0.4	0.8	0.6	0.4
	wet	0.6	0.6	0.8	0.7	1.0
Organic matter (%)		8.66	4.46	4.73	1.83	0.79
CEC (meq/100g)		28.09	24.44	22.36	15.60	13.00
Ca (meq/100g)		10.00	6.50	6.50	5.13	4.81
Mg (meq/100g)		4.13	2.75	2.25	1.15	1.23
K (meq/100g)		0.96	0.87	0.74	0.35	0.32

I Information on the site

a. Profile Number: COC 6.
b. Soil Name:
c. Higher Category Classification:
Soil Taxonomy: Typic Dystropept.
ICOMAND: Typic Dystropept.
d. Date of Examination: 29 February 1987.
e. Author: Gerard Baltisse and André Nieuwenhuyse.
f. Location: 400 meters north of the river Penitencia, 1 km west of the road to Cocori, 15 km. north of Cariari, Limon province, Costa Rica.
g. Elevation: less than 20 meters.
h. Land form:
i. physiographic position: former river plain.
ii. surrounding land form: almost flat.
iii. microtopography: nil.
i. Slope on which profile is sited: flat (0%).
j. Land-use:between 1975 and 1980 the area is deforestated, after which it has been used for corn. At this moment it is not in use and we find a secondary vegetation (about 3 meters high.
k. Climate: Total annual rainfall is about 4500 mm. and the mean annual temperature is about 23.5 C. The week before this description was sunny and dry.

II General Information on the Soil

a. Parent material: fluvial sands of volcanic origin.
b. Drainage: Class 4 - well drained.
c. Moisture conditions in profile: moist until 80 cm. deeper than 80 cm. the soil is wet.
d. Depth of groundwater table: 90 cm.
e. Presence of surface stones, rock outcrops: none.
f. Evidence of erosion: none.
g. Evidence of compaction: pseudogley occurs in surface horizon as a result of compaction, this horizon also contains less pores.
h. Human influence: none.
i. Soil fauna: earthworms.

III Profile Description

Agh 0 - 5 cm
Very dark grayish brown (10 YR 3/2) moist and dark brown (10 YR 4/3) dry, common fine distinct red and gray mottles; loam; moderate to strong very fine subangular blocky; slightly sticky, slightly plastic, friable moist, slightly thixotropic wet; common very fine and few medium pores; common very fine, fine and medium roots; abrupt wavy boundary; pH 5.1.

Ah 5 - 30 cm
Dark brown (10 YR 3/3) moist and yellowish brow (10 YR 5/4) dry, sandy loam; porous massive with a tendency to weak subangular blocky; slightly sticky, slightly plastic, very friable moist, thixotropic wet; many very fine and few medium pores; common very fine and few medium roots; clear wavy boundary; Ph 5.8.

Bgc 30 - 80 cm
Very dark grayish brown (10 YR 3/2) moist and yellowish brown (10 YR 5/4) dry, common fine distinct gray and orange mottles; loamy sand; porous massive; slightly sticky, slightly plastic, friable moist, thixotropic wet; many very fine and common fine and medium pores; very few small soft irregular red ironstone nodules; common very fine and medium roots; clear wavy boundary; pH 6.3.

C 80 - 120 cm
Brownish black (10 YR 3/2) moist; sand; loose.

IV Chemical and physical analysis

Profile number:	COC 6			
Depth of horizon (cm)			5	30	80
Physical analyses					
Bulk density	(g/cc)		0.72	1.02	1.13
Liquid Limit	(%)	dry	55	54	54
		wet	89	28	36
Plasticity Index	(%)	dry	1	10	6
		wet	27	--	--
@ during sampling	(%)		75	45	43
@ at pF4.2	(%)	dry	19.4	8.9	8.2
		wet	26.2	17.5	10.3
texture:	sand	(%)	56	56	72
	loam	(%)	31	35	21
	clay	(%)	13	9	7
Chemical analyses					
pH-H2O		dry	5.1	5.8	6.3
		wet	4.4	4.8	5.0
pH-H2O, paper.			5.3	5.3	5.7
pH-KCl		dry	4.5	4.7	5.0
		wet	4.5	4.7	4.7
pH-NaF after 2 min.		dry	9.8	10.7	10.0
		wet	9.3	10.6	9.3
pH-NaF after 60 min.		dry	10.5	11.4	10.7
		wet	10.0	11.3	10.2
pH-NaF with paper.			9.5	10.0	9.0
phosphate ret.	(%)	dry	59.6	60.8	50.9
		wet	28.7	39.1	23.4
Acid oxalate extractable					
	Al	dry	2.4	0.5	0.3
		wet	0.6	0.7	0.3
	Fe	dry	1.4	0.8	1.0
		wet	1.0	1.0	0.9
	Si	dry	0.1	0.2	0.1
		wet	0.1	0.2	0.1
KOH extractable Al		dry	0.4	0.5	0.2
		wet	0.5	0.4	0.2
Organic matter	(%)		8.93	1.57	1.61
CEC	(meq/100g)		19.24	18.72	11.44
Ca	(meq/100g)		10.63	4.63	6.06
Mg	(meq/100g)		3.25	0.88	2.13
K	(meq/100g)		0.83	0.61	0.45

I Information on the site

a. Profile Number: COC 8
b. Soil Name:
c. Higher Category Classification:
Soil taxonomy: Typic Dystropept.
ICOMAND: Andic Dystropept.
d. Date of Examination: 2 March 1987.
e. Author:André Nieuwehuyse and Gerald Baltissen.
f. Location: 1 km. north of the Penetencia river, 1500 m. west of the road to Cocori, 15 km. north of Cariari, Limon province, Costa Rica.
g. Elevation: Less than 20 meters.
h. Land form:
i. physiographic position: former river plain.
ii. surrounding land form: almost flat.
iii. microtopography: nil.
i. Slope on which profile is sited: flat (0%).
j. Vegetation: primary forest.
k. Climate: Total annual rainfall is about 4500 mm. and the mean annual temperature is about 23.5 C. The week before this description was normal in rain and temperature.

II General Information on the Soil

a. Parent material: fluvial sands of volcanic origin.
b. Drainage: Class 3 - moderately well drained.
c. Moisture conditions in profile: moist until 60 cm, below 60 cm. wet.
d. Depth of groundwater table: 77 cm.
e. Presence of surface stones, rock outcrops: none.
f. Evidence of erosion: none.
g. Evidence of compaction: none.
h. Human influence: none.
i. Soil fauna: many earthworms, ants, termites, rats and mouses.

III Profile Description

A 0 - 12 cm
Very dark grayish brown (10 YR 3/2) moist and dark brown (10 YR 4/3) dry, loam; moderate very fine angular blocky and very fine and fine granular; slightly sticky, slightly plastic, very friable moist, slightly thixotropic wet; common very fine and fine, and few medium pores; abundant roots of all sizes; clear wavy boundary; pH 4.8.

Bw 12 - 30 cm
Dark yellowish brown (10 YR 4/4) moist and yellowish brown (10 YR 5/4) dry, loam; moderate very fine subangular blocky and fine granular; slightly sticky, slightly plastic, very friable moist, thixotropic wet; many very fine and few medium pores; many roots of all sizes; clear wavy boundary; pH 4.9.

Bcg 30 - 55 cm
Dark yellowish brown (10 YR 4/4) moist and yellowish brown (10 YR 5/4) dry, many medium distinct orange and gray mottles; sandy loam; weak very fine subangular blocky; slightly sticky, slightly plastic, friable moist, thixotropic wet; many very fine pores; few small soft irregular red ironstone nodules; common fine and medium roots; clear smooth boundary; pH 5.6.

BC 55 - 70 cm
Dark yellowish brown (10 YR 4/4) moist and dry, sand; porous massive; friable moist, thixotropic wet; common very fine pores; common fine and medium roots; clear smooth boundary; pH 5.7.

C 70 - 80 cm
Very dark grayish brown (10 YR 3/2) moist, sand; single grain; no roots.

IV Chemical and physical analysis

Profile number:	COC 8				
Depth of horizon	(cm)	12	30	55	70
Physical analyses					
Bulk density	(g/cc)	0.68	0.81	0.99	1.20
Liquid Limit	(%) dry	58	52	--	--
	wet	105	78	18	--
Plasticity Index	(%) dry	2	4	--	--
	wet	44	20	--	--
@ during sampling	(%)	89	70	57	45
@ at pF4.2	(%) dry	24.3	18.8	8.2	--
	wet	37.0	39.8	10.9	7.9
texture: sand	(%)	36	40	86	64
loam	(%)	54	48	8	28
clay	(%)	10	12	6	8
Chemical analyses					
pH-H2O	dry	4.8	4.9	5.6	5.7
	wet	4.2	4.3	4.4	4.5
pH-H2O, paper.		5.0	5.5	5.5	6.0
pH-KCl	dry	4.2	4.3	4.4	4.5
	wet	4.1	4.5	5.1	5.0
pH-NaF after 2 min.	dry	10.5	10.7	10.5	10.0
	wet	10.2	10.6	10.0	8.9
pH-NaF after 60 min.	dry	11.1	11.4	11.2	10.8
	wet	10.8	11.3	11.2	10.9
pH-NaF with paper.		9.5	10.0	10.0	9.0
phosphate ret.	(%) dry	100.2	79.4	81.3	49.6
	wet	51.8	52.4	44.4	44.5
Acid oxalate extractable					
Al	dry	0.6	0.7	0.7	1.4
	wet	0.7	0.8	0.5	0.4
Fe	dry	1.1	1.2	2.5	0.2
	wet	1.0	1.2	1.0	0.9
Si	dry	0.1	0.2	0.2	0.0
	wet	0.1	0.2	0.2	0.1
KOH extractable Al	dry	0.5	0.5	0.4	0.4
	wet	0.6	0.6	0.4	0.4
Organic matter	(%)	9.65	4.29	2.14	0.25
CEC	(meq/100g)	28.60	23.40	15.08	11.44
Ca	(meq/100g)	8.75	3.63	2.56	2.50
Mg	(meq/100g)	2.50	1.00	0.70	0.61
K	(meq/100g)	0.42	0.32	0.22	0.22

I Information on the site

a. Profile Number: COC 24.
b. Soil Name: Suelo Sardina.
c. Higher Category Classification:
Soil taxonomy: Fluventic Dystropept.
ICOMAND: Andic Dystropept.
d. Date of Examination: 16 May 1987.
e. Author: Gerard Baltissen and André Nieuwehuyse
f. Location: About 1350 meters west of the road to Cocori, about 150 m. north-west of the river Penetencia, approximately 15 km. north of Cariari, Limon province, Costa Rica, approximately 83 44'E; 10 32'N.
g. Elevation: about 20 meters.
h. Land form:
i. physiographic position: former river plain.
ii. surrounding land form:flat.
iii. microtopography: nil.
i. Slope on which profile is sited: almost flat (1%).
j. Land-use: grassland.
k. Climate: Total annual rainfall is about 4500 mm. and the mean annual temperature is about 23.5 C.

II General Information on the Soil

a. Parent material: sandy riversediment, probable of volcanic origin.
b. Drainage: Class 4 - well drained.
c. Moisture conditions in profile: moist throughout.
d. Depth of groundwater table: 150 cm.
e. Presence of surface stones, rock outcrops: none.
f. Evidence of erosion: none.
g. Evidence of compaction: pseudogley in the upper 5 cm.
h. Human influence: none.
i. Soil fauna: earthworms.

III Profile Description

Agh 0 - 5 cm
Very dark gray (10 YR 3/1) moist and dark brown (10 YR 3/3) dry, common fine distinct clear red mottles; loam; weak fine and medium angular blocky; slightly sticky, slightly plastic, firm moist, slightly thixotropic wet; very few fine pores; many very fine and fine roots; clear wavy boundary; pH 5.0.

Bu1 5 - 40 cm
Yellowish brown (10 YR 5/4) moist and dry, loam;partly strong fine and medium crumb, partly moderate very fine subangular blocky; slightly sticky, slightly plastic, friable moist, thixotropic wet; many very fine and few medium pores; many very fine and common fine roots; clear smooth boundary; pH 5.7.

Bu2 40 - 50 cm
Yellowish brown (10 YR 5/4) moist and light yellowish brown (10 YR 6/4) dry, loamy sand; massive porous; non-sticky, non-plastic, very friable moist; many very fine and few medium and coarse pores; common very fine roots; clear smooth boundary; pH 6.2.

Bg1 50 - 70 cm
Yellowish brown (10 YR 5/4) moist and dry, common medium distinct clear brown mottles; sandy loam; massive porous with 25% moderate fine and medium crumb; slightly sticky, slightly plastic, very friable moist, very thixotropic wet; many very fine, common fine and medium and few coarse pores; common very fine roots; gradual smooth boundary; pH 5.1.

Bg2 70 - 110 cm
Yellowish brown (10 YR 5/6) moist and light yellowish brown (10 YR 6/4) dry, many medium distinct clear gray and orange mottles; silt loam; moderate very fine angular and subangular blocky with 20% moderate fine and medium crumb; slightly sticky, slightly plastic, friable moist, very thixotropic wet; many very fine. common fine and medium and few coarse pores; few very fine roots; pH 6.1.

IV Chemical and physical analysis

Profile number:	COC 24				
Depth of horizon (cm)		5	40	50	70	110
Physical analyses						
Bulk density (g/cc)		0.74	0.87	0.97	0.86	0.82
Liquid Limit (%)	dry	87	62	--	41	54
	wet	129	79	--	49	63
Plasticity Index (%)	dry	12	--	--	2	1
	wet	22	4	--	--	32
@ during sampling (%)		71	48	36	57	61
@ at pF4.2 (%)	dry	35.1	24.4	7.8	14.5	20.0
	wet	39.5	27.7	12.0	18.7	35.3
texture: sand (%)		28	26	60	34	16
loam (%)		50	56	30	52	66
clay (%)		22	18	10	14	18
Chemical analyses						
pH-H2O	dry	5.0	5.7	6.2	6.0	6.1
	wet	4.7	4.8	4.8	4.9	5.0
pH-H2O, paper.		5.3	5.3	5.7	5.9	5.5
pH-KCl	dry	4.5	4.7	4.8	4.8	4.9
	wet	4.8	4.7	4.6	4.7	4.8
pH-NaF after 2 min.	dry	9.0	10.1	10.3	10.1	9.9
	wet	9.5	10.2	10.1	10.1	9.7
pH-NaF after 60 min.	dry	9.5	11.0	11.1	10.9	10.7
	wet	10.2	11.1	11.0	10.9	10.7
pH-NaF with paper.		9.0	9.0	9.5	9.0	9.0
phosphate ret. (%)	dry	90.3	68.3	70.4	71.4	75.1
	wet	29.0	48.3	46.2	39.4	51.8
Acid oxalate extractable						
Al	dry	0.4	0.6	0.5	0.6	0.5
	wet	0.4	0.6	0.6	0.7	0.6
Fe	dry	1.3	1.5	1.0	2.5	0.4
	wet	1.1	1.3	0.9	1.1	1.7
Si	dry	0.1	0.1	0.2	0.2	0.2
	wet	0.1	0.1	0.2	0.2	0.2
KOH extractable Al	dry	0.3	0.3	0.3	0.3	0.2
	wet	0.3	0.4	0.5	0.4	0.3
Organic matter (%)		12.86	3.48	1.07	0.80	1.07
CEC (meq/100g)		28.60	23.92	17.68	17.68	31.20
Ca (meq/100g)		17.50	12.50	5.44	8.75	12.50
Mg (meq/100g)		5.00	4.25	1.20	2.63	4.50
K (meq/100g)		0.93	1.16	0.45	0.45	0.58

I. Information on the site

a. Profile Number: COC 25.
b. Soil Name: Suelo Sardina.
c. Higher Category Classification:
Soil taxonomy: Aquic Dystropept.
ICOMAND: Aquic Dystropept.
d. Date of Examination: 16 May 1987.
e. Author: Gerard Baltissen and André Nieuwehuyse.
f. Location: About 1400 meters west of the road to Cocori, about 170 meters north-west of the river Penetencia, approximately 15 km. north of Cariari, Limon province, Costa Rica, Approximately 83 44'E; 10 32'N.
g. Elevation: about 20 meters.
h. Land form:
i. physiographic position: former river plain.
ii. surrounding land form: flat.
iii. microtopography: pit is situated in an old track where bulldozers dragged trees out of the forest.
i. Slope on which profile is sited: flat (0%).
j. Land-use: grassland.
k. Climate: Total annual rainfall is about 4500 mm. and the mean annual temperature is about 23.5 C.

II General Information on the Soil

a. Parent material: sandy riversediment, probably of volcanic origin.
b. Drainage: Class 3 - moderately well drained.
c. Moisture conditions in profile: moist throughout.
d. Depth of groundwater table: deeper than the profile.
e. Presence of surface stones, rock outcrops: none.
f. Evidence of erosion: none
g. Evidence of compaction: very compacted.
h. Human influence: compacted by bulldozers.
i. Soil fauna: not seen.

III Profile Description

Ah 0 - 10 cm
Very dark gray (10 YR 3/1) moist and dark yellowish brown (10 YR 4/4) dry, common fine distinct clear and diffuse red and orange mottles; loam with small parts of wood; moderate fine angular blocky; slightly sticky, slightly plastic, friable moist, slightly thixotropic wet; very few very fine pores; abundant very fine and fine roots; abrupt smooth boundary; pH 5.9.

Bg1 10 - 17 cm
Brown (10 YR 5/3) moist and light yellowish brown (10 YR 6/4) dry, common fine distinct clear orange mottles; loam; weak medium and coarse angular blocky; slightly sticky, slightly plastic, very firm moist, slightly thixotropic wet; very few very fine pores; patchy moderately thick cutans, probably of clay minerals with iron oxides and hydroxides, on ped faces; few very fine roots in between peds; abrupt irregular boundary; pH 5.1.

Bg2 17 - 23 cm
Dark gray (5 Y 4/1) moist and light yellowish brown (10 YR 6/4) dry, common medium prominent clear and sharp orange mottles; loam; weak coarse angular blocky with a tendency to massive; slightly sticky, slightly plastic, very firm moist, slightly thixotropic wet; very few very fine pores; patchy to broken, moderately thick cutans, probably of clay minerals with iron oxides and hydroxides, on ped faces; few very fine roots in between peds; clear irregular boundary; pH 5.1.

Bg3 23- 30 cm
Yellowish brown (10 YR 5/6) moist and yellowish brown (10 YR 5/4) dry, common fine faint diffuse orange and gray mottles; loam; massive porous; slightly sticky, slightly plastic, firm moist, slightly thixotropic wet; many very fine partly discontinuous pores; few fine roots; pH 5.8.

IV Chemical and physical analysis

Profile number:	COC 25			
Depth of horizon (cm)	10	17	23	30
Physical analyses				
Bulk density (g/cc)	0.96	0.88	0.83	0.82
Liquid Limit (%) dry	--	64	67	65
wet	--	84	90	88
Plasticity Index (%) dry	--	21	10	11
wet	--	26	27	32
@ during sampling (%)	56	69	76	80
@ at pF4.2 (%) dry	11.5	23.2	24.1	24.5
wet	--	37.1	39.1	42.3
texture: sand (%)	72	--	--	10
loam (%)	22	--	--	54
clay (%)	6	--	--	26
Chemical analyses				
pH-H2O dry	5.9	5.1	5.1	5.8
wet	--	4.4	4.9	4.7
pH-H2O, paper.	5.3	5.0	5.5	5.7
pH-KCl dry	4.7	4.3	4.2	4.7
wet	--	4.3	4.8	5.3
pH-NaF after 2 min. dry	10.5	9.8	9.8	9.7
wet	--	9.6	9.6	9.5
pH-NaF after 60 min. dry	11.2	10.5	10.6	10.5
wet	--	10.4	10.4	10.4
pH-NaF with paper.	9.0	9.0	8.5	9.0
phosphate ret. (%) dry	72.3	82.5	82.5	75.4
wet	--	54.2	48.6	35.8
Acid oxalate extractable				
Al dry	0.5	0.6	0.6	0.5
wet	--	0.7	0.8	0.6
Fe dry	0.8	1.8	1.8	1.7
wet	--	1.8	1.8	1.7
Si dry	0.1	0.1	0.2	0.1
wet	--	0.1	0.2	0.2
KOH extractable Al dry	0.4	0.4	0.4	0.4
wet	--	0.4	0.2	0.2
Organic matter (%)	1.61	--	--	0.80
CEC (meq/100g)	16.64	--	--	23.92
Ca (meq/100g)	4.44	--	--	13.13
Mg (meq/100g)	0.85	--	--	2.13
K (meq/100g)	0.67	--	--	0.45

I. Information on the site

a. Profile Number: RJZ 22.
b. Soil Name: Suelo Union.
c. Higher Category Classification:
d. Date of Examination: 1 May 1987.
e. Author: Rien Dam.
f. Location: Two kilometers north west of Río Jimenez, 100 meters north of the road, Limon province, map sheet of Gu cimo 3446 I, 579.78 W; 248.73 N, Costa Rica.
g. Elevation: 15 meters.
h. Land form:
   i. physiographic position: plain formed by a mud-flow.
   ii. surrounding land form: flat.
   iii. microtopography: nil.
i. Slope on which profile is sited: almost flat (0%).
j. Land-use: mixed culture with yucca, cassava and grassland.
k. Climate: Total annual rainfall is about 4500 mm. and the mean annual temperature is about 23.5 C. The week before this description was cloudy and rainy.

II General Information on the Soil

a. Parent material: sand with gravel and stones, deposited by a mud-flow.
b. Drainage: Class 4 - well drained.
c. Moisture conditions in profile: All the profile is moist.
d. Depth of groundwater table: deeper than the profile.
e. Presence of surface stones, rock outcrops: none.
f. Evidence of erosion: none.
g. Evidence of compaction: none.
h. Human influence: none.
i. Soil fauna: earthworms.

III Profile Description

Ah1 0 - 20 cm

Very dark grayish brown (10 YR 3/2) moist and dark brown (10 YR 3/3) dry, sandy loam; weak very fine subangular blocky with 20% porous massive; slightly sticky, slightly plastic, very friable moist, very thixotropic wet; many very fine discontinuous vesicular pores; very few fresh gravel; abundant very fine to coarse roots; clear wavy boundary; pH 5.3.

Ah2 20 - 64 cm

Very dark brown (10 YR 2/2) moist and dark grayish brown (10 YR 4/2) dry, slightly gravelly sandy loam; strong very fine angular blocky with 20% porous massive; slightly sticky, slightly plastic, very friable moist, very thixotropic wet; many very fine discontinuous tubular pores; very few fresh gravel; common very fine and fine roots; abrupt smooth boundary; pH 5.6.

C 64 - 90 cm

Very dark grayish brown (10 YR 3/2) moist and grayish brown (10 YR 5/2) dry, gravelly sand; massive; non-sticky,non-plastic,very friable moist; few very fine vesicular continuous pores; frequent angular fresh gravel; few very fine roots; clear wavy boundary; pH 6.2.

IV Chemical and physical analysis

Profile number:	RJZ 22			
Depth of horizon	(cm)	20	64	90
Physical analyses				
Bulk density	(g/cc)	0.86	0.71	1.30
Liquid Limit	(%) dry	68	70	--
	wet	66	67	--
Plasticity Index	(%) dry	11	--	--
	wet	10	3	--
@ during sampling	(%)	44	61	12
@ at pF4.2	(%) dry	27.4	32.2	5.9
	wet	29.4	38.5	7.0
texture:	sand (%)	65	75	89
	loam (%)	25	17	5
	clay (%)	10	8	6
Chemical analyses				
pH-H2O	dry	5.3	5.6	6.2
	wet	4.9	5.8	6.2
pH-H2O, paper.		5.5	5.5	5.9
pH-KCl	dry	4.8	5.2	5.5
	wet	4.8	5.2	5.2
pH-NaF after 2 min.	dry	11.2	11.4	10.5
	wet	11.1	11.5	10.3
pH-NaF after 60 min.	dry	11.8	11.9	11.3
	wet	11.8	12.0	11.3
pH-NaF with paper.		10.0	10.0	9.5
phosphate ret.	(%) dry	97.1	96.8	75.4
	wet	66.9	78.8	35.8
Acid oxalate extractable				
Al	dry	2.4	3.1	0.8
	wet	2.9	3.4	1.0
Fe	dry	0.8	0.8	0.3
	wet	0.9	0.8	0.3
Si	dry	1.0	1.3	0.5
	wet	1.2	1.3	0.5
KOH extractable Al	dry	1.0	1.4	0.5
	wet	0.6	1.0	0.4
Organic matter	(%)	3.9	0.3	10.2
CEC	(meq/100g)	40.9	33.0	14.5
Ca	(meq/100g)	6.4	3.8	2.1
Mg	(meq/100g)	1.8	0.7	0.5
K	(meq/100g)	0.5	0.2	0.2
Na	(meq/100g)	0.30	0.26	0.25

I. Information on the site

a. Profile Number: RJZ 24

b. Soil Name: Suelo Cristina.

c. Higher Category Classification:
Soil taxonomy: Hydric Dystropept.
ICOMAND: Typic Hapludand.

d. Date of Examination: 1 May 1987.

e. Author: Rien Dam.

f. Location: 2 kilometers west of Río Jiménez, 200 meters south of the road to Cartagena, 100 meters east of the Jardin river, Limon province, map sheet of Gu cimo 3446 I, 578.4 W; 248.4 N, Costa Rica.

g. Elevation: 15 meters.

h. Land form:
i. physiographic position: plain formed by a mud-flow.
ii. surrounding land form: flat.
iii. microtopography: nil.

i. Slope on which profile is sited: flat (0%).

j. Land-use: cacao, lemon dulce (sort of citrus) and orange trees.

k. Climate: Total annual rainfall is about 4500 mm. and the mean annual temperature is about 23.5 C. The week before the description was cloudy and rainy.

II General Information on the Soil

a. Parent material: sand with gravel, deposited by a mud-flow and from volcanic origin.

b. Drainage: Class 4 - well drained.

c. Moisture conditions in profile: Moist throughout.

d. Depth of groundwater table: 2.3 meters.

e. Presence of surface stones, rock outcrops: none.

f. Evidence of erosion: none.

g. Evidence of compaction: none.

h. Human influence: none.

i. Soil fauna: earthworms and ants.

III Profile Description

Ap 0 - 15 cm
Very dark grayish brown (10 YR 3/2) moist and dark brown (10 YR 4/3) dry, loam; moderate very fine subangular blocky; slightly sticky, slightly plastic, very friable moist, very thixotropic wet; many micro and very fine vesicular discontinuous pores and few fine and medium tubular continuous pores; abundant very fine and moderate roots; clear wavy boundary; pH 5.3.

Au 15 - 50 cm
Dark brown (10 YR 3/3) moist and dark brown (7.5 YR 4/4) dry, loam; moderate very fine subangular blocky with 10% very fine crumb; slightly sticky, slightly plastic, very friable moist, very thixotropic wet; many very fine and medium tubular continuous pores; common very fine and fine roots; clear wavy boundary; pH 5.6.

Bw 50 - 85 cm
Dark yellowish brown (10 YR 4/4) moist and light yellowish brown (10 YR 6/4) dry, clay loam; moderate very fine subangular blocky; slightly sticky, slightly plastic, very friable moist, very thixotropic wet; frequent very fine discontinuous and frequent fine and moderate continuous tubular pores; common very fine and fine roots; clear wavy boundary; pH 5.7.

BC 85 - 110 cm
Dark brown (10 YR 3/3) moist and brown (10 YR 5/3) dry, sand; weak very fine subangular blocky; non-sticky, non-plastic, very friable moist, slightly thixotropic wet; few very fine and fine tubular continuous pores; gradual wavy boundary; pH 6.0.

C 110 - 130 cm
Dark brown (10 YR 3/3) moist and brown (10 YR 5/3) dry, sand; loose; very few angular fresh gravel; pH 6.2.

IV Chemical and physical analysis

Profile number:	RJZ 24					
Depth of horizon	(cm)		15	50	85	110	130
Physical analyses							
Bulk density	(g/cc)		0.56	0.67	1.06	--	--
Liquid Limit	(%)	dry	66	85	44	--	--
		wet	97	87	42	--	--
Plasticity Index	(%)	dry	6	10	5	--	--
		wet	18	15	--	--	--
@ during sampling	(%)		88	76	43	--	--
@ at pF4.2	(%)	dry	28.2	40.4	18.3	5.1	5.4
		wet	47.8	44.9	23.3	7.2	6.5
texture:	sand	(%)	55	55	43	59	27
	loam	(%)	37	37	39	27	57
	clay	(%)	8	8	18	14	16
Chemical analyses							
pH-H2O		dry	5.3	5.6	5.7	6.0	6.2
		wet	5.1	5.7	5.0	5.9	5.7
pH-H2O, paper.			5.3	5.7	5.0	5.7	5.7
pH-KCl		dry	4.7	4.9	4.2	4.4	4.3
		wet	4.6	5.1	4.2	4.4	4.3
pH-NaF after 2 min.		dry	11.0	11.3	10.4	10.0	9.7
		wet	10.9	11.3	10.3	10.0	9.9
pH-NaF after 60 min.		dry	11.8	11.9	11.1	10.7	10.4
		wet	11.7	11.9	10.4	10.8	10.6
pH-NaF with paper.			10.0	10.0	9.0	9.0	9.0
phosphate ret.	(%)	dry	97.8	98.7	84.4	58.3	54.9
		wet	68.4	76.7	59.8	20.7	81.7
Acid oxalate extractable							
	Al	dry	2.7	2.1	0.8	0.7	0.5
		wet	2.7	2.6	0.8	0.4	0.3
	Fe	dry	1.5	1.1	0.5	2.2	1.5
		wet	0.9	1.0	0.4	0.2	0.3
	Si	dry	0.9	0.9	0.3	0.3	0.2
		wet	1.0	1.0	0.3	0.2	0.1
KOH extractable Al		dry	0.6	0.9	0.4	0.3	0.1
		wet	1.1	1.1	0.4	0.4	0.3
Organic matter	(%)		2.41	0.13	0.26	0.56	6.29
CEC	(meq/100g)		46.9	31.0	26.4	21.0	36.3
Ca	(meq/100g)		7.5	3.8	8.8	8.8	18.1
Mg	(meq/100g)		0.4	1.3	2.1	2.5	6.5
K	(meq/100g)		3.7	2.6	1.2	0.3	0.2
Na	(meq/100g)		0.3	0.3	0.4	0.4	0.5

I. Information on the site

a. Profile Number: RJZ 25.
b. Soil Name: Suelo Chirripo.
c. Higher Category Classification:
   Soil taxonomy: Hydric Dystropept.
   ICOMAND: Typic Hapludand.
d. Date of Examination: 1 May 1987.
e. Author: Rien Dam.
f. Location: 5.5 kilometers west of Río Jiménez, 500 meters north of the road to Gu cimo, 10 meters east of the road that goes to the north, Limon province, map sheet of Gu cimo 3446 1, 574.6 W; 248.4 N, Costa Rica.
g. Elevation: 19 meters.
h. Land form:
   i. physiographic position: alluvial plain.
   ii. surrounding land form: flat.
   iii. microtopography: nil.
i. Slope on which profile is sited: flat (0%).
j. Land-use: corn.
k. Climate: Total annual rainfall is about 4500 mm. and the mean annual temperature is about 23.5 C. The week before this description was cloudy and rainy.

II General Information on the Soil

a. Parent material: alluvial sands with volcanic origin.
b. Drainage: Class 3 - moderately well drained.
c. Moisture conditions in profile: moist throughout.
d. Depth of groundwater table: 77 cm.
e. Presence of surface stones, rock outcrops: none.
f. Evidence of erosion: none.
g. Evidence of compaction: none.
h. Human influence: none.
i. Soil fauna: earthworms, ants and various types of larvas.

III Profile Description

Ah1 0 - 25 cm
Very dark grayish brown (10 YR 3/2) moist and dark brown (10 YR 4/3) dry, silty clay loam; moderate fine subangular blocky; slightly sticky, slightly plastic, very friable moist, thixotropic wet; frequent micro, very fine and fine tubular continuous pores; common very fine, fine and medium roots; gradual irregular boundary; pH 5.3.

Ah2 25 - 56 cm
Very dark grayish brown (10 YR 3/2) moist and dark brown (10 YR 4/3) dry, silty clay loam; moderate fine subangular blocky with 30% very fine and fine crumb;
slightly sticky, slightly plastic, very friable moist, very thixotropic wet; frequent micro, very fine, fine and medium tubular continuous pores; common very fine, fine and medium roots; clear smooth boundary; pH 5.6.

Bw 56 - 80 cm
Yellowish brown (10 YR 5/6) moist and light yellowish brown (10 YR 6/4) dry, sandy loam, massive porous, slightly sticky, slightly plastic, firm moist, very thixotropic wet; frequent micro and common very fine continuous tubular pores; clear irregular boundary; pH 5.9.

C 80 - 97 cm
Dark brown (10 YR 3/3) moist and light yellowish brown (10 YR 6/4) dry, sand; massive to weak very fine angular blocky; non-sticky, non-plastic, very friable moist, very thixotropic wet; few very fine continuous tubular pores; clear wavy boundary; pH 6.1.

2Cg 97 - 112 cm
Yellowish brown (10 YR 5/4) moist, many fine faint diffuse gray mottles; clay loam; moderate fine subangular blocky; slightly sticky, slightly plastic, very friable moist, thixotropic wet; few fine tubular continuous pores.

IV Chemical and physical analysis

Profile number:	RJZ 25			
Depth of horizon (cm)	25	56	80	97
Physical analyses				
Bulk density (g/cc)	0.62	0.51	0.81	1.13
Liquid Limit (%) dry	75	71	59	41
wet	95	88	58	49
Plasticity Index (%) dry	--	6	9	--
wet	15	1	4	--
@ during sampling (%)	81	101	73	43
@ at pF4.2 (%) dry	33.9	28.7	19.4	12.6
wet	44.7	53.5	30.6	19.8
texture: sand (%)	59	49	69	75
loam (%)	37	41	37	17
clay (%)	8	10	8	8
Chemical analyses				
pH-H2O dry	5.3	5.6	5.9	6.1
wet	5.2	5.7	5.8	6.1
pH-H2O, paper.	5.3	5.7	5.3	5.7
pH-KCl dry	4.8	4.9	5.1	5.0
wet	4.9	5.0	5.2	5.1
pH-NaF after 2 min. dry	10.6	11.5	10.9	10.6
wet	10.7	11.4	11.5	10.4
pH-NaF after 60 min. dry	11.5	12.0	11.6	11.3
wet	11.7	12.0	11.7	11.2
pH-NaF with paper.	9.5	10.0	10.0	10.0
phosphate ret. (%) dry	90.3	100.2	93.4	82.5
wet	58.1	81.7	59.8	46.5
Acid oxalate extractable				
Al dry	2.0	3.1	2.7	1.9
wet	2.0	3.9	3.1	1.8
Fe dry	1.0	1.4	0.9	1.1
wet	0.8	1.1	0.4	0.2
Si dry	0.8	1.4	1.8	1.4
wet	0.8	1.4	1.7	1.0
KOH extractable Al dry	0.3	1.0	0.2	0.3
wet	0.8	0.8	1.0	0.6
Organic matter (%)	5.6	0.9	0.5	4.2
CEC (meq/100g)	47.5	38.9	23.1	17.8
Ca (meq/100g)	12.5	3.2	2.4	6.6
Mg (meq/100g)		1.1	1.0	4.5
K (meq/100g)	0.6	0.3	0.4	0.5
Na (meq/100g)	0.34	0.33	0.29	0.32

I. Information on the site

a. Profile Number: Eg 2.
b. Soil Name: Suelo Silencio.
c. Higher Category Classification:
   Soil taxonomy: Humoxic Tropohumult.
   ICOMAND: Humoxic Tropohumult.
d. Date of Examination: 24 April 1987.
e. Author: Egbert Spaans.
f. Location: parcel number 74 in the Neguev, 15 meters east of the road, Limon province, map sheet of Gu cimo 3446 I, 587.2 W; 245.2 N, Costa Rica.
g. Elevation: 24 meters.
h. Land form:
   i. physiographic position: mud-flow.
   ii. surrounding land form: hilly.
   iii. microtopography: nil.
i. Slope on which profile is sited: moderately steep (20%).
j. Land-use: grassland for live-stock.
k. Climate: Total annual rainfall is about 3950 mm. and the mean annual temperature is about 24.5 C.

II General Information on the Soil

a. Parent material: volcanic material from the vulcan Turrialba.
b. Drainage: Class 4 - well drained.
c. Moisture conditions in profile: not surveyed.
d. Depth of groundwater table: deeper than the profile.
e. Presence of surface stones, rock outcrops: none.
f. Evidence of erosion: none.
g. Evidence of compaction: A-horizon very compacted.
h. Human influence: none.
i. Soil fauna: ants, earthworms, termites and "tortusas".

III Profile Description

Agh 0 - 10 cm
Dark brown (10 YR 4/3) moist and dark yellowish brown (10 YR 4/4) dry, many fine distinct sharp gray and brown mottles; clay; strong very fine angular blocky; slightly sticky, plastic, friable moist; frequent very fine continuous pores; common very fine roots; abrupt smooth boundary; pH 4.6.

Bw1 10 - 34 cm
Dark brown (7.5 YR 4/4) moist and dry, clay; moderate fine angular blocky with 30% weak fine crumb; slightly sticky, plastic, very friable moist; many very fine and common fine pores; common very fine roots; clear wavy boundary; pH 4.4.

Bw2 34 - 150 cm
Dark brown (7.5 YR 4/4) moist and dry, clay; moderate fine angular blocky with 30% weak fine crumb; slightly sticky, plastic, firm moist; many very fine and few fine pores; few very fine roots; pH 4.6.

IV Chemical and physical analysis

Profile number:	EG 2			
Depth of horizon	(cm)	10	34	150
Physical analyses				
Bulk density	(g/cc)	0.90	0.75	0.80
Liquid Limit	(%) dry	82	77	82
	wet	87	358	115
Plasticity Index	(%) dry	25	18	14
	wet	20	291	42
@ during sampling	(%)	56	60	60
@ at pF4.2	(%) dry	32.3	33.1	34.2
	wet	45.3	45.6	47.8
texture:	sand (%)	14	4	6
	loam (%)	28	24	22
	clay (%)	58	72	72
Chemical analyses				
pH-H2O	dry	4.6	4.4	4.6
	wet	3.9	4.1	4.7
pH-H2O, paper.		4.7	4.7	4.4
pH-KCl	dry	3.9	3.9	3.8
	wet	3.7	3.7	3.8
pH-NaF after 2 min.	dry	9.2	9.7	9.7
	wet	9.0	9.6	9.5
pH-NaF after 60 min.	dry	9.9	10.5	10.7
	wet	9.4	10.2	10.5
pH-NaF with paper.		9.0	9.0	9.0
phosphate ret.	(%) dry	66.2	61.4	76.9
	wet	50.1	56.0	54.5
Acid oxalate extractable				
	Al dry	0.5	0.4	0.6
	wet	0.4	0.4	0.4
	Fe dry	0.8	0.3	0.5
	wet	0.3	0.2	0.1
	Si dry	0.1	0.1	0.2
	wet	0.0	0.0	0.0
KOH extractable Al	dry	0.4	0.3	0.3
	wet	0.4	0.6	0.5
Organic matter	(%)	8.82	2.68	1.16
CEC	(meq/100g)	19.61	14.84	12.72
Ca	(meq/100g)	0.81	0.44	0.25
Mg	(meq/100g)	1.33	0.36	0.30
K	(meq/100g)	0.29	0.16	0.16

I. Information on the site

a. Profile Number: Eg 3.
b. Soil Name: Suelo Milano.
c. Higher Category Classification:
Soil Taxonomy: Typic Dystropept.
ICOMAND: Typic Dystropept.
d. Date of Examination: 25 April 1987.
e. Author: Egbert Spaans.
f. Location: parcel number 238 in the Neguev, 200 meters north of the road and east of the river Germania, Limon province, map sheet of Gu cimo 3446 I, 586.2 W; 240.0 N, Costa Rica.
g. Elevation: 59 meters.
h. Land form:
i. physiographic position: high part of a mud-flow.
ii. surrounding land form: undulating.
iii. microtopography: nil.
i. Slope on which profile is sited: sloping (8%).
j. Land-use: not in use, secondary forest coming up.
k. Climate: Total annual rainfall is about 3950 mm. and the mean annual temperature is about 24.5 C.

II General Information on the Soil

a. Parent material: volcanic material from the vulcan Turrialba.
b. Drainage: Class 4 - well drained.
c. Moisture conditions in profile: not surveyed.
d. Depth of groundwater table: deeper than the profile.
e. Presence of surface stones, rock outcrops: none.
f. Evidence of erosion: none.
g. Evidence of compaction: none.
h. Human influence: none.
i. Soil fauna: ants, termites and earthworms.

III Profile Description

Ah 0 - 4 cm
Dark brown (10 YR 4/3) moist and dark brown (7.5 YR 4/4) dry, silty clay loam; moderate fine granular; slightly sticky, slightly plastic, very friable moist, slightly thixotropic wet; few very fine pores; many very fine, many fine and few moderate roots; abrupt smooth boundary; pH 4.4.

Bw1 4 - 30 cm
Dark brown (10 YR 4/3) moist and dark brown (7.5 YR 4/4) dry, clay loam; weak very fine crumb; slightly sticky, slightly plastic, friable moist, thixotropic wet; many very fine and few fine pores; few very fine and few fine roots; clear wavy boundary; pH 4.4.

Bw2 30 - 75 cm
Dark brown (10 YR 4/3) moist and dark brown (7.5 YR 4/4) dry, clay loam; weak very fine crumb; slightly sticky, slightly plastic, very friable moist, very thixotropic wet; few parts of strongly weathered very thixotropic volcanic tuff; many very fine and few fine pores; few very fine roots; abrupt smooth boundary; pH 4.4.

C 75 - 77 cm
Dark brown (10 YR 4/3) moist and dry, common coarse distinct sharp black mottles of manganese; loam; massive porous; slightly sticky, non-plastic, very firm moist, very thixotropic wet; many very fine pores.

IV Chemical and physical analysis

Profile number:	EG 3			
Depth of horizon	(cm)	4	30	54
Physical analyses				
Bulk density	(g/cc)	---	0.96	0.86
Liquid Limit	(%) dry	49	50	57
	wet	71	70	72
Plasticity Index	(%) dry	1	4	11
	wet	16	14	18
@ during sampling	(%)	---	55	54
@ at pF4.2	(%) dry	24.3	23.9	25.3
	wet	29.0	35.1	37.0
texture:	sand (%)	18	28	28
	loam (%)	48	44	40
	clay (%)	34	28	32
Chemical analyses				
pH-H2O	dry	4.4	4.4	4.4
	wet	4.1	4.3	4.5
pH-H2O, paper.		5.0	5.3	5.3
pH-KCl	dry	4.2	4.3	4.5
	wet	4.1	4.3	4.6
pH-NaF after 2 min.	dry	9.5	10.1	10.1
	wet	8.8	9.8	9.4
pH-NaF after 60 min.	dry	10.6	11.1	11.0
	wet	10.3	10.9	10.6
pH-NaF with paper.		9.0	9.5	9.0
phosphate ret.	(%) dry	56.4	73.2	72.3
	wet	45.3	58.1	64.3
Acid oxalate extractable				
Al	dry	2.4	0.7	0.5
	wet	0.6	0.5	0.5
Fe	dry	2.3	0.5	0.5
	wet	0.4	0.5	0.5
Si	dry	0.2	0.2	0.2
	wet	0.0	0.1	0.1
KOH extractable Al	dry	0.5	0.5	0.5
	wet	0.6	0.6	0.5
Organic matter	(%)	8.82	3.06	1.53
CEC	(meq/100g)	17.49	11.66	8.48
Ca	(meq/100g)	2.50	0.50	0.31
Mg	(meq/100g)	2.00	0.48	0.35
K	(meq/100g)	0.77	0.26	0.16

I. Information on the site

a. Profile Number: Eg 4.
b. Soil Name: Suelo Milano.
c. Higher Category Classification:
   Soil taxonomy: Oxic Humitropept.
   ICOMAND: Andic Humitropept.
d. Date of Examination: 25 April 1987.
e. Author: Egbert Spaans.
f. Location: parcel number 238 in the Neguev, 25 meters north east of the south boundary, Limon province, map sheet of Gu cimo 3446 I, 589.0 W; 237.8 N, Costa Rica.
g. Elevation: 44 meters.
h. Land form:
   i. physiographic position: high part of a mud-flow.
   ii. surrounding land form: undulating.
   iii. microtopography: nil.
i. Slope on which profile is sited: flat (0%).
j. Land-use: grassland for live-stock.
k. Climate: Total annual rainfall is about 3950 mm. and the mean annual temperature is about 24.5 C.

II General Information on the Soil

a. Parent material: volcanic material from the vulcan Turrialba.
b. Drainage: Class 4 - well drained.
c. Moisture conditions in profile: not surveyed.
d. Depth of groundwater table: deeper than the profile.
e. Presence of surface stones, rock outcrops: none.
f. Evidence of erosion: none.
g. Evidence of compaction: the A-horizon is very compacted.
h. Human influence: none.
i. Soil fauna: ants, termites and earthworms.

III Profile Description

Agh1 0 - 10 cm
Dark brown (10 YR 4/3) moist and dry, common fine distinct sharp gray and brown mottles; clay loam; strong very fine angular blocky; slightly sticky, slightly plastic, friable moist, slightly thixotropic wet; many very fine pores; many very fine roots; abrupt smooth boundary; pH 5.1.

Agh2 10 - 30 cm
Dark brown (10 YR 4/3) moist and dark brown (7.5 YR 4/4) dry, common fine distinct sharp gray and brown mottles; clay; moderate very fine angular blocky; slightly sticky, slightly plastic, firm moist, thixotropic wet; common very fine pores; common very fine roots; clear smooth boundary; pH 5.1.

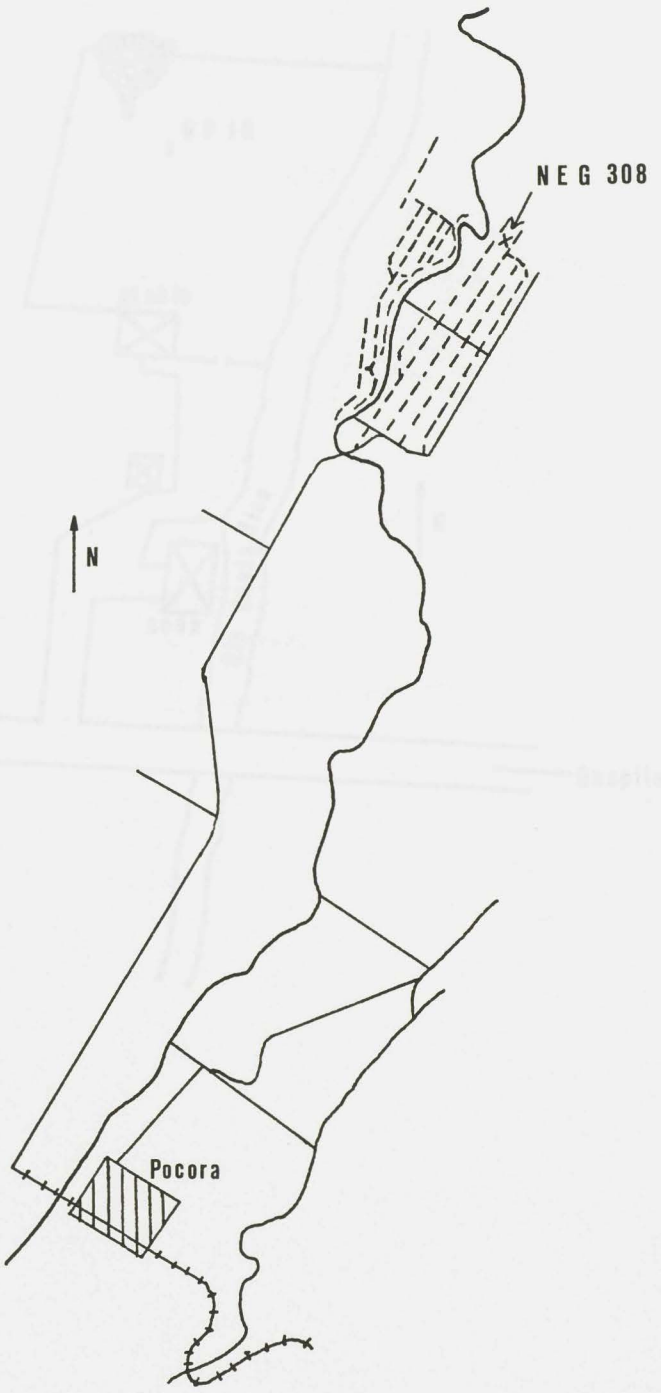
Bw1 30 - 65 cm
Dark yellowish brown (10 YR 4/4) moist and dark brown (10 YR 4/4) dry, clay loam; weak very fine crumb; slightly sticky, slightly plastic, very friable moist, thixotropic wet; many very fine and few fine pores; common very fine roots; abrupt wavy boundary; pH 5.0.

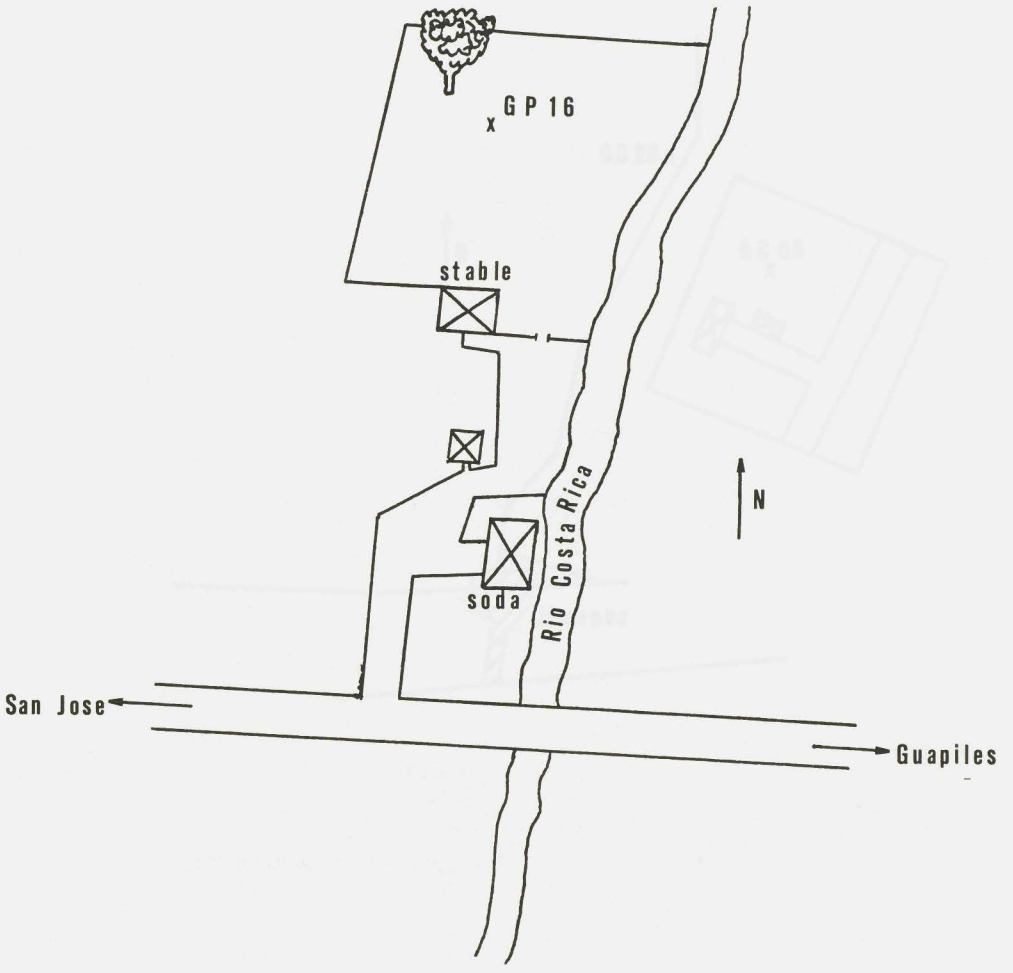
Bw2 65 - 120 cm
Dark yellowish brown (10 YR 4/4) moist and dark brown (7.5 YR 4/4) dry, gravelly very stony clay loam; weak very fine crumb; slightly sticky, slightly plastic, very friable moist, thixotropic wet; frequent angular weathered gravel, very frequent angular weathered stones; many very fine pores; few very fine roots; pH 5.0.

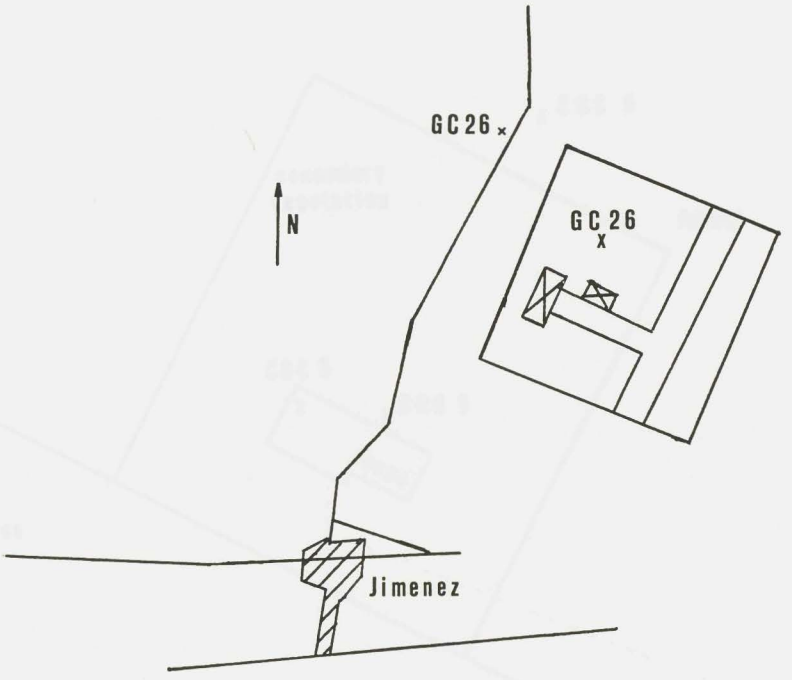
IV Chemical and physical analysis

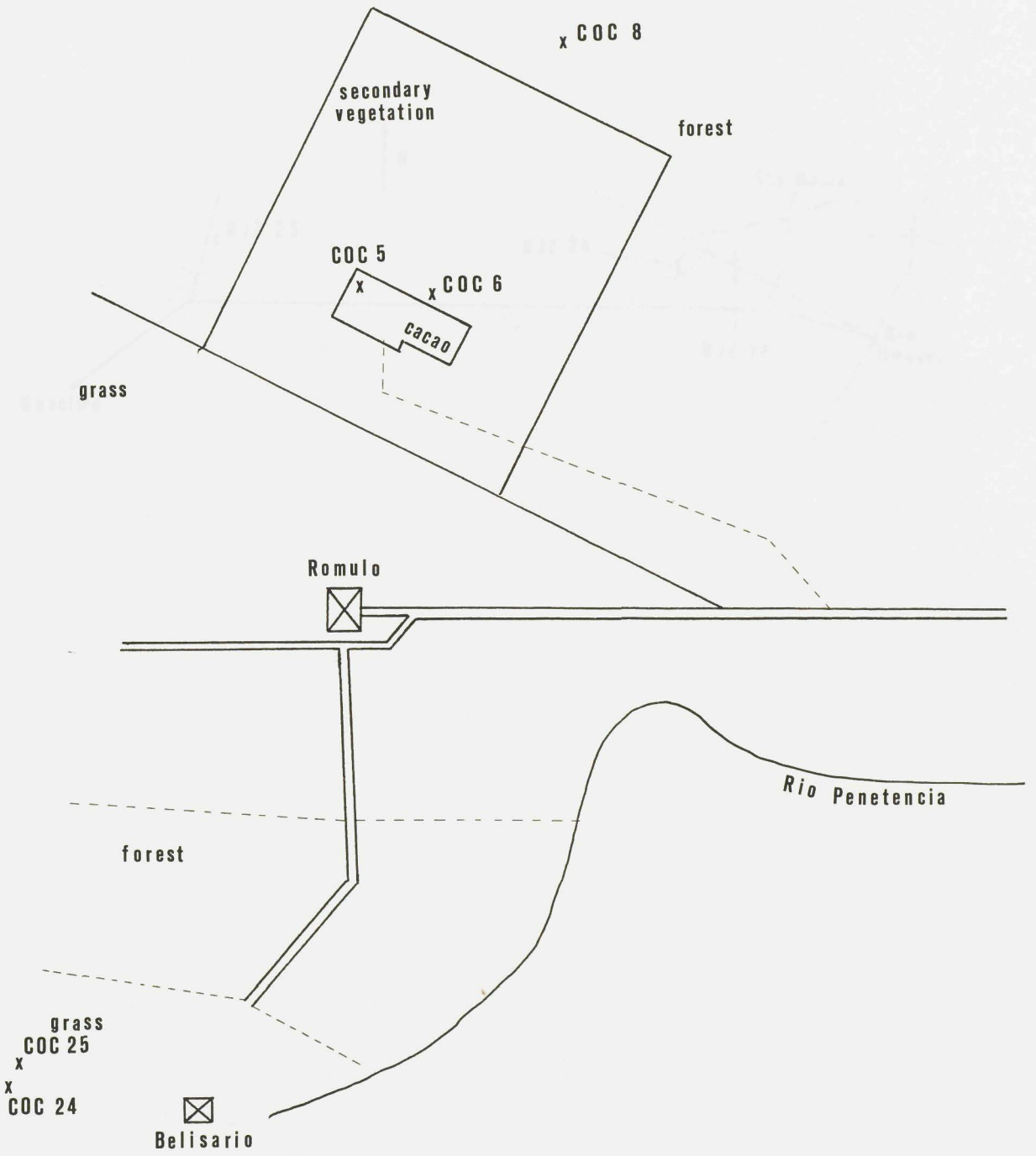
Profile number:	EG 4				
Depth of horizon (cm)		10	30	65	120
Physical analyses					
Bulk density (g/cc)		0.85	0.97	0.96	0.96
Liquid Limit (%)	dry	56	52	51	55
	wet	79	76	74	61
Plasticity Index (%)	dry	3	5	4	5
	wet	12	18	18	7
@ during sampling (%)		46	53	48	55
@ at pF4.2 (%)	dry	26.1	26.4	26.5	27.9
	wet	36.9	35.8	37.6	40.6
texture: sand (%)		24	26	30	--
loam (%)		40	32	32	--
clay (%)		36	42	38	--
Chemical analyses					
pH-H2O	dry	5.1	5.1	5.0	5.0
	wet	4.4	4.7	4.8	4.8
pH-H2O, paper.		5.3	5.5	5.0	5.0
pH-KCl	dry	4.1	4.1	4.1	4.2
	wet	4.1	4.1	4.1	4.1
pH-NaF after 2 min.	dry	9.8	10.0	10.4	10.2
	wet	9.5	9.9	10.1	10.1
pH-NaF after 60 min.	dry	10.7	11.1	11.3	11.2
	wet	10.6	11.0	11.2	11.1
pH-NaF with paper.		9.0	10.0	10.0	10.0
phosphate ret. (%)	dry	60.1	76.6	77.9	76.3
	wet	81.7	82.6	69.3	64.6
Acid oxalate extractable					
Al	dry	0.8	0.8	0.7	0.7
	wet	0.8	0.7	0.7	0.6
Fe	dry	0.7	0.6	0.5	0.5
	wet	0.7	0.5	0.5	0.5
Si	dry	0.2	0.1	0.1	0.1
	wet	0.2	0.1	0.1	0.1
KOH extractable Al	dry	0.7	0.7	0.7	0.9
	wet	0.8	0.8	1.0	1.0
Organic matter (%)		10.35	5.74	2.31	--
CEC (meq/100g)		21.73	19.96	13.25	--
Ca (meq/100g)		3.81	2.50	1.31	--
Mg (meq/100g)		3.00	1.06	0.50	--
K (meq/100g)		0.39	0.19	0.13	--

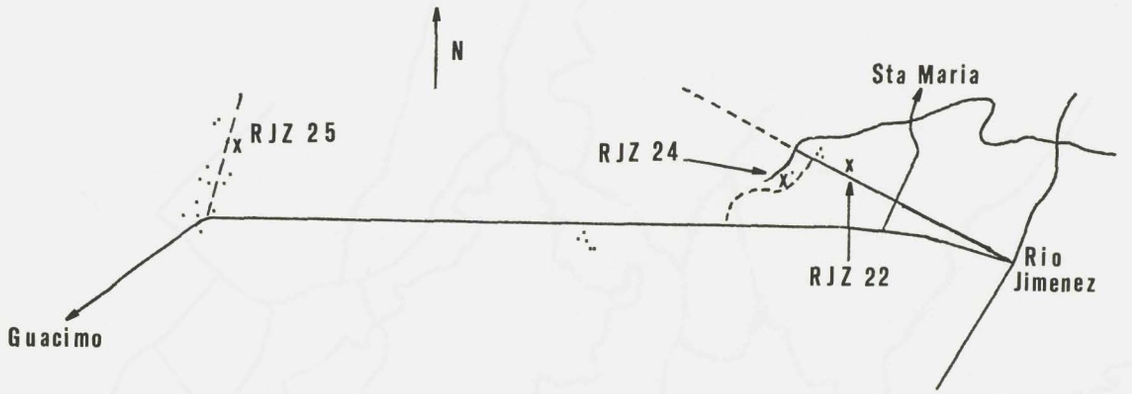
Appendix V: Exact locations of the pits.

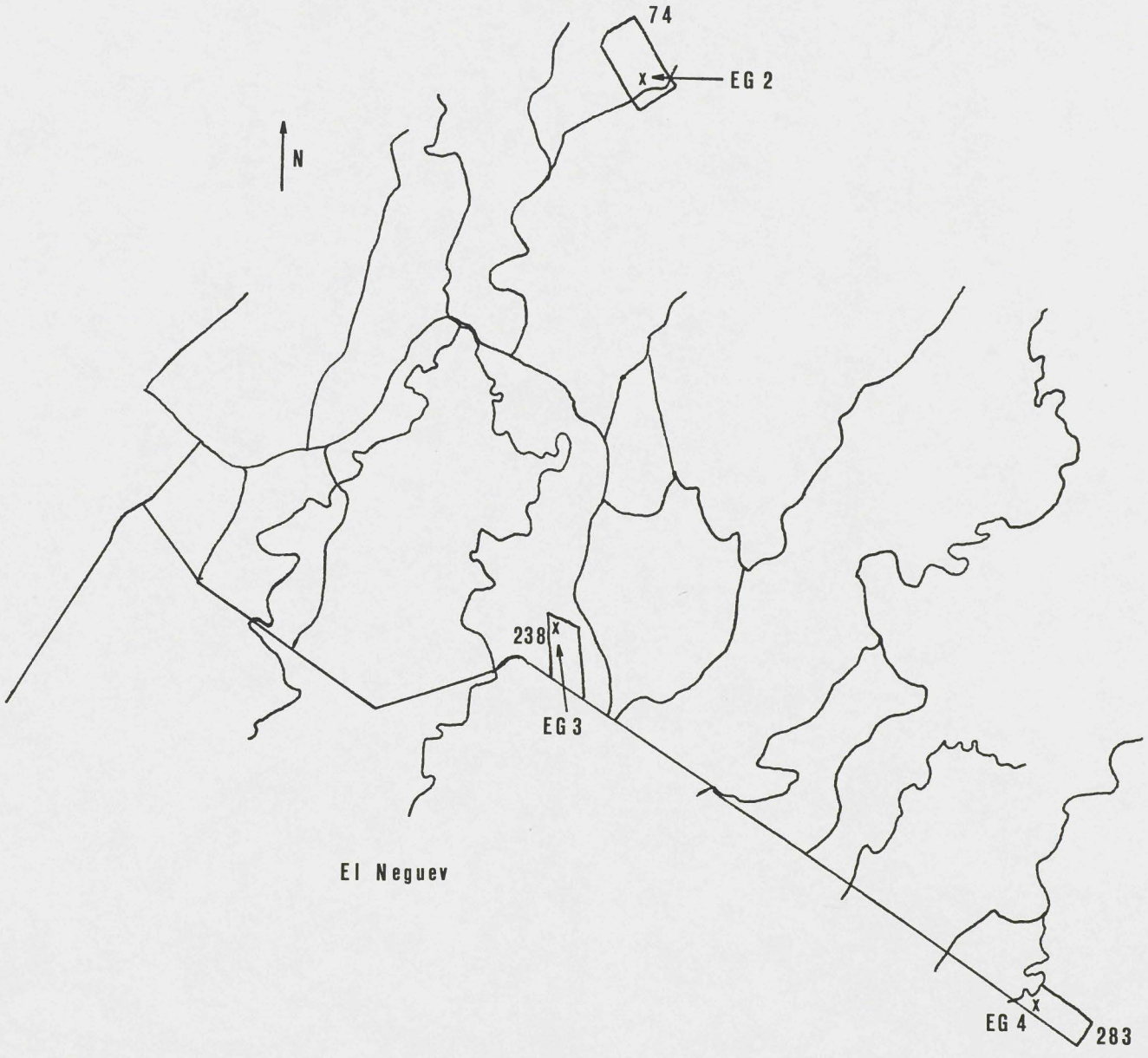



GP 16
stable
soda
Rio Costa Rica
N
San Jose
Guapiles


GC 26
N
GC 26
Jimenez


COC 8
secondary vegetation
forest
COC 5
COC 6
cacao
grass
Romulo
Rio Penetencia
forest
grass
COC 25
COC 24
Belisario


N
Sta Maria
RJZ 25
RJZ 24
RJZ 22
Rio
Jimenez
Guacimo



El Neguev